

MOTORS AND MOTORING

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HENRY J. SPOONER

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MOTORS AND MOTORING

BY
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PREFACE

WITH the object of assisting beginners to acquire useful information relating to motors and motoring, the author consented to write this little work, much of the matter consisting of what may be considered an introduction to the mechanics of motoring. He has endeavored to explain things in non-technical language as far as practicable, and in such a way that those who have not the time, inclination, or opportunity to study any of the large books on the subject, may easily be able to get a general grasp of the principles which underlie the construction, assembling, and working of gasoline cars.

The Gasolene Engine System is first dealt with, and a careful examination of Fig. 1, with the assistance of the accompanying text, should enable the reader to understand the relationship and interdependence of its various parts; these parts being further dealt with in separate articles, not the least important of which is No. 12, on the Float-Feed Carburettor, which is explained with the assistance of Fig. 6, specially devised to show, on a single drawing, the important features of the best-known carburettors, an expedient the author has found very useful for educational purposes.

Most of the figures are diagrammatic, and have been drawn in such a way as to give prominence to their important features, whilst, for simplicity sake, minor details have been omitted; the leading parts being shaped that their functions can be best understood by the novice, and these remarks particularly apply to Figs. 18 and 19.

No attempt has been made to describe any particular car, as the details of construction of any one make nec-

essarily differ in many respects from all others. But the author hopes that the contents of the following pages will help the novice to trace out easily the run of the various connections, pipes, leads, etc., on a given car, and to understand quickly its general arrangement and working, and also become acquainted with the methods of adjustment and lubrication peculiar to it. All this can be much facilitated by referring to the Instruction Books now supplied with most cars, and by reading week by week one or more of the admirable technical journals which so loyally and ably represent, promote, and encourage the pastime and industry. Although, due to the exigencies of space, the author has had to confine himself mainly to motor cars, it should not be overlooked that gasolene motors, whether they be used to propel cars, boats, cycles, or machinery, have much in common.

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INTRODUCTION

1. No one can fail to notice the growing interest the typical "man in the street" is taking in Motors¹ and Motoring. His eyes instinctively turn critically to view each passing car, and he knows that a peculiar ticking noise is a sure indication of the approach of an electric carriage, and light puffs of steam from underneath a car² a certain sign that it is a steam vehicle, whilst his ear is so delicately attuned to the wide range of detonations, due to the working of gasolene motors, that he is rarely at fault in placing such cars in the right category; but should he be in doubt, the offensive odor³ of the exhaust gases from the cars too often give his olfactory organ an opportunity of assisting in the matter, and he is generally able to differentiate between the various types of cars in use. Presumably he has not failed to notice that the electric car is used almost exclusively for town work, often in the form of a brougham. Its great weight for a comparatively small power, the limited distance it can run without recharging the batteries, to say nothing of its cost, and the cost of running, precludes this otherwise almost perfect car from use for touring purposes, so that for long dis-

¹ Motor is a recognized abbreviation of "Motor Car"; strictly speaking, the *motor* is the *engine*, whilst a motor car, *autocar*, or *automobile*, as it is sometimes called, is the name for both carriage and motor.

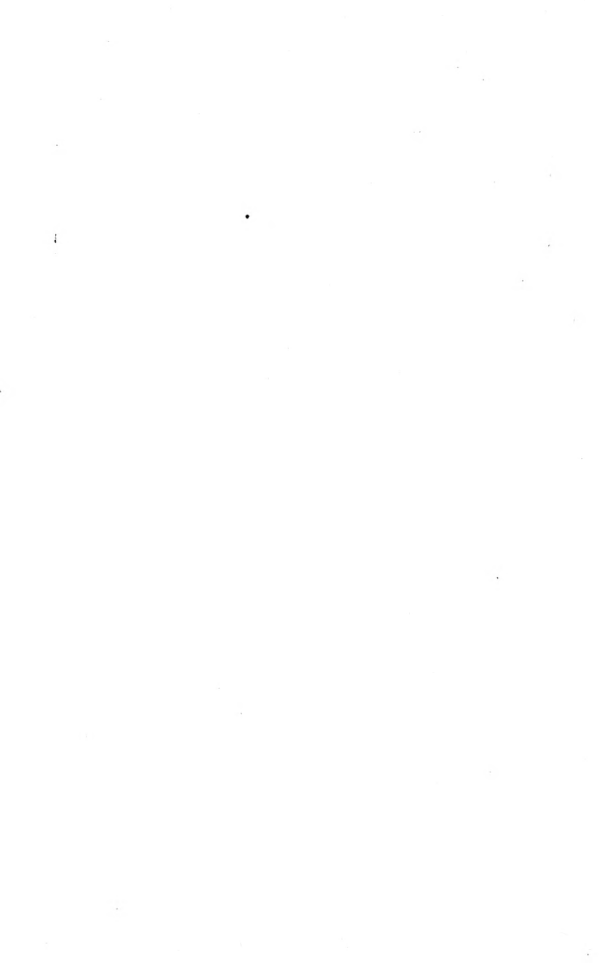
² It should be mentioned that some of the best makes seldom, if ever, show any exhaust.

³ The obnoxious odor of the exhaust gases that so often offend, is largely due to the condensation of gasolene vapor which occurs before the engine, etc., is properly warmed up, and to the volatilization of unsuitable lubricating oil used in excess in the cylinders, or to its unsuitable quality. Refer to articles 69 and 70.

tances only steam and gasolene cars are at present available; and, for reasons which will be explained later, comparatively few of the former are now running. Thus the gasolene engine is used in the great majority of cars now running, to say nothing of the enormous and rapidly increasing number of motor bicycles now in use, in which the motive power is the gasolene engine. This doubtless accounts for the kind of motor language that is heard at every turn, and, if the truth must be known, by the boy in the school; for, strangely enough, the schoolboy's allegiance to the locomotive has been wavering in favor of the automobile for some time, and now his school-locker generally contains a rare collection of pictures, plates, post cards, technical journals, and parts of models relating to autocars and motor bicycles, instead of such things concerning the various types of locomotives that were formerly so much in favor;¹ indeed, it is often astonishing to see what an amount of intelligent interest all kinds of people take in the arrangement and working of motor vehicles. This is particularly displayed whenever a car is stopped in a public street, and its hood is lifted for a moment or two; the usual crowd, which seems to spring from the road itself, immediately surrounds the car, and much advice, more or less pertinent, is freely offered, and although the unhappy motorist may not profit much by it, he cannot fail to be impressed with the growing knowledge the "man in the street" has of autocar matters. Of course, this knowledge is in most cases very superficial and unsound, and requires to be organized and supplemented by a good grasp, or at least a rudimentary knowledge, of the principles which underlie and govern the construction and working of the motor, before it is of any practical use. So the author, in arranging the articles in this little work, has

¹ In this connection there cannot be a doubt that the great progress we are making in automobilism has had not a little to do with the astonishing increase in the number of boys whose greatest ambition is to become engineers.

endeavored to explain in simple, and as far as possible in non-technical, language the principles of construction and working that every potential motorist and driver should be acquainted with before he attempts to drive a car upon the road.



MOTORS AND MOTORING

THE CHOICE OF A CAR

2. The matter of the selection of a car is one on which it is practically impossible to give any adequate advice. The prospective buyer, if he be wise, will have looked over the field very carefully before he comes to a final decision. Some idea of the range of power, price, and kind of cars that are now upon the American market may be formed by a study of the various periodicals devoted to the automobile sport and industry. At the show in the Madison Square Garden at New York last winter there were exhibited between two and three hundred makes of American cars. The New York Importers' Salon showed about fifty different designs. These cars ranged from three and a half and four horse power machines, costing \$375, up to the forty, fifty, and sixty and even ninety horse power cars, some of which cost as high as \$15,000. A pretty good idea of price may be derived from the saying that a motor car costs \$100 a horse power and \$1 a pound. There are exceptions to this rule—machines of sixteen and eighteen horse power, quoted at under \$1,000—but it represents the average. Of the cars, American and foreign, now on the market, ninety per cent. are propelled by the gasoline explosive engine. Makers seem to be fairly evenly divided as to the merits of bevel and chain driving. The desire for greater power has forced most of the American makers to place on the market four-cylinder cars, but these are of necessity comparatively high priced, and for light touring the two-cylinder and single-cylinder cars are still satisfactory. The man who knows what he wants, when he buys a car, will usually be able to obtain reasonable concessions from

the dealer. For instance, there may be a point or two about which he is not absolutely satisfied. The make of carburettor may not be to his liking, and he may ask for one of another and higher grade. Few dealers will be likely to let a matter of this kind prevent a sale.

ELEMENTS OF A MOTOR CAR

3. Every car, whether it be driven by electricity, steam, or gasoline, consists of two principal parts, namely, *the carriage body* and the *chassis*.¹ The former is practically complete in itself; the latter embodies the following principal elements: the frame, to which the motor proper and its accessories are attached—the transmission gear (including the chains in chain-driven cars)—axles, springs, road wheels, steering gear, etc.

A complete car, with all its fittings and accessories, appears to most novices a very complicated vehicle, but when it is carefully examined, and the function of each element and fitting understood, it really is often a fairly simple machine; particularly is this so in cars that have not been overloaded with refinements and fittings of doubtful utility. It has frequently been remarked that the general appearance of a car (with the exception of an electric one) is often no sure indication of the arrangement of its component parts, or the type of its motor, as makers have, with very few exceptions, adopted the outward form that everyone is familiar with, and to accomplish this have even, in some cases, put on dummy fittings and accessories. This tendency is particularly noticeable where a characteristic feature of some famous car is so imitated that at first sight it is not easy even for an expert to name the maker. It is a practice much to be deprecated, more particularly as some of the designers who have thus

¹This French word has become Anglicized. In France, when strictly used, it means the *frame* only.

sinned have produced cars of such excellence that they should well be able to hold their own without such adventitious assistance. On the other hand, for obvious reasons, there is much to be said in favor of co-ordinating in new cars, as far as is practicable, the driving fittings and arrangements (more particularly the pedals and brake levers), with those which are considered best arranged on the leading cars. It will now be convenient to give some detailed attention to the various *elements* of the gasolene car, commencing with the motor.

THE GASOLENE MOTOR

Elements of the Complete Engine

4. As has been explained in footnote 1 to page xii, the word motor, when strictly used, refers to the engine which drives the car or cycle; but as the term is often very loosely used, even by experts, who of course know exactly what they are talking about and to what they refer, it will be well to make clear that for our purpose the gasolene motor will be considered to be the complete working engine, one that could either be used to drive a car, a boat, or any other machine, such as a lathe, where power is to be transmitted to some rotating part. That is to say, the motor must embody the engine proper, and such auxiliaries as the carburettor, induction coil, accumulator, etc. The engine proper, as we have called it, is diagrammatically represented by Figs. 2 to 5. It is often referred to as the *Motor*; so to be clear on this point, before we further proceed, it must be understood that when we use the word Motor the complete system is referred to. Needless to say, this explanation is given to prevent that confusion of thought and meaning which too often hamper the progress of the tyro who is studying the internal economy of the Motor Car. The first lesson in the art and pastime of motoring might very appropriately be a brief descrip-

tion of the Gasolene Motor, and to facilitate this the author has made a diagrammatic sketch (Fig. 1) of what may be called the *complete system*, which shows the engine in relation to the subsidiary elements of the complete motor. Obviously, the component parts are arranged in such a way, in relation to one another, as to show at a glance their interdependence, and enable the beginner to get a grasp of the principles which govern the working of the machine; this means that all the parts must be arranged in the same plane, and some of them made to appear larger than they would be if they were drawn to scale. In other words, we have a distorted sketch, showing the elements spread out for ready inspection;¹ and a careful examination of the figure will enable the reader to become familiar with the technical names of the most important elements, details, etc., which will greatly assist him in understanding the description of the motor which is to follow.

¹ It should be hardly necessary to explain that for a fixed position of the engine on the frame of the car, the auxiliary elements of the motor can be fixed in an infinite number of positions in relation to one another, so long as they are connected up as shown in the figure.

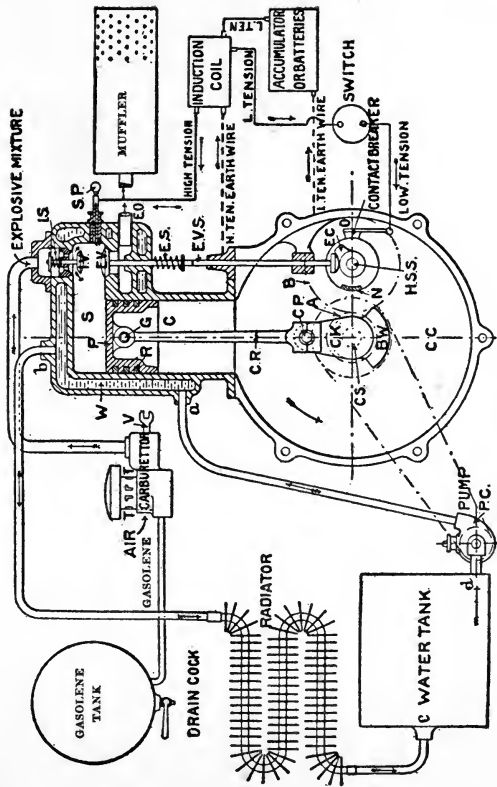


Fig. 1.

THE GASOLENE MOTOR.

DIAGRAMMATIC SKETCH OF THE COMPLETE SYSTEM, DISTORTED, AND PARTS ARRANGED
TO SHOW AT A GLANCE THEIR INTERDEPENDENCE

REFERENCE NOTES FOR FIG. 1.

C. Cylinder	V. Rod for control of Throttle	B.W. Crank Balance-Weight
W. Water Cooling Jacket	E.O. Exhaust Outlet	H.S.S. Half-Speed Shaft
P. Piston	E.V.S. Exhaust Valve Spindle	C.S. Crank-Shaft
R. Piston Rings	E.C. Exhaust Valve Cam	S. Combustion Chamber or Space
I. V. Inlet Valve	A. and B. Two-to-One Gear Wheels	G. Gudgeon or Pitson-Pin
E. V. Exhaust Valve	C.C. Crank-Case	S.P. Sparking Plug
E.S. Spring to hold the Exhaust Valve down	CK. Crank	I.S. Spring to hold Inlet Valve up
T.T. Supplementary Air Inlets	C.R. Connecting Rod	P.C. Circulating Pump
	C.P. Crank-Pin	N. Brass Sector

DESCRIPTION OF THE GASOLENE MOTOR

Or "Internal-Combustion Engine"

5. As has been explained, the motor, although an element of the car, is a complete heat engine, consisting of a number of elements ingeniously arranged in relation to one another to form a whole working machine, in which the potential energy of the gasolene is converted into moving energy at the crank-shaft (C.S., Fig. 1). All gasolene engines in general use are reciprocating ones, that is to say, the straight line motion of the piston (P., Fig. 1) is converted into the circular motion of the crank-shaft by means of a connecting-rod (C.R., Fig. 1) and crank (CK., Fig. 1). Now, every single cylinder reciprocating engine must be fitted with a fly-wheel,¹ fixed to the crank-shaft, to carry the crank over the dead-center;² but in the gas engine this wheel has also another function to perform, which can better be explained after we have made clear what goes on in the cylinder during the engine's complete cycle.

THE OTTO CYCLE

6. The gasolene motor is an "internal-combustion engine," that is to say, one in which a mixture of gasolene vapor and air, automatically made in an element called the carburettor (by the action of the engine), in such proportions as to form an explosive mixture, is drawn into the cylinder by the engine itself and electrically ignited, causing combustion to occur, and the

¹This wheel is not shown on the diagram; it generally also forms the outer shell of the friction clutch. In cycle motors the fly-wheel and crank are usually combined.

²When the crank and connection rod come into the same straight line, obviously no pressure on the piston, however great, could cause the crank-shaft to turn, but by fixing a fly-wheel to the crank-shaft, the momentum given to it during the working stroke of the piston carries the crank over the *dead-center*, as it is called.

piston to be pushed down with great force by the pressure of the burning and expanding gases, this pressure on the piston being transmitted through the connecting rod to the crank-shaft.

The series of operations which take place in the cylinder to form a complete cycle correspond to four strokes of the piston and two revolutions of the crank-shaft, and these operations make up what is called the Otto cycle, after Dr. Otto,¹ who introduced it in 1876 in his "Silent" gas engine.

THE FOUR STROKES

An examination of Figs. 2 to 5 (which have been drawn, with the positions of certain parts slightly altered, so that each essential detail can be seen quite distinctly, to conveniently illustrate this description) will enable the reader to be clear about what occurs during each stroke.

1st. The Suction or Charging Stroke (Fig. 2).—During the first out-stroke of the piston a partial vacuum is formed, and, the piston acting as a pump, the explosive mixture is drawn into the cylinder through the inlet valve, the spring of which is only sufficiently strong to hold up the valve on its seat.

2nd. The Compression Stroke (Fig. 3).—During the return or in-stroke, both the inlet and exhaust valves are closed, and the explosive mixture, which was drawn in during the previous stroke, is compressed by the piston into the clearance space (or combustion chamber).

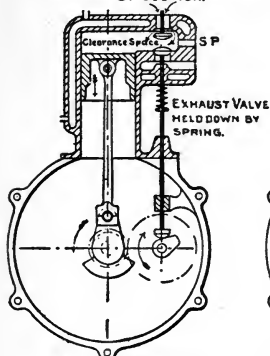
¹The four-stroke cycle was first suggested by Beau de Rochas in 1862, but the gas engine invented by Dr. Otto, and made by Crossley Brothers, first established the economy and efficiency of internal-combustion engines working on this cycle. The invention was the subject of a patent granted in 1876, No. 2081, to C. D. Abel, for improvements in gas motor engines (a communication from abroad by N. A. Otto).

THE GASOLENE-ENGINE

DIAGRAMMATIC DRAWINGS SHOWING THE FOUR STROKES OF THE OTTO CYCLE.

Fig. 2.

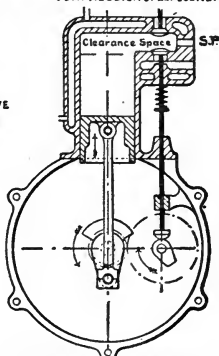
INLET VALVE OPENED TO EXPLOSIVE MIXTURE
BY SUCTION.



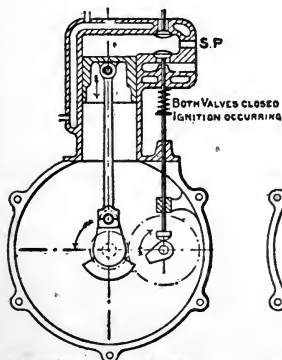
I SUCTION STROKE

Fig. 3.

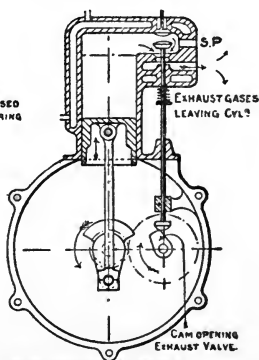
BOTH VALVES CLOSED DURING
COMPRESSION OF EXPLOSIVE MIXTURE



II COMPRESSION STROKE



III EXPLOSION STROKE



IV EXHAUST STROKE

Fig. 4.

Fig. 5.

3rd. The Explosion and Expansion Stroke (Fig. 4).—The compressed charge is ignited by an electric spark (or an incandescent tube¹) after the crank has just passed the dead-center; and the pressure, due to the heat energy, developed by the combustion, so rapidly rises that, before the piston has appreciably moved on this second *forward* or *working* stroke, it reaches its maximum, and work is done on the piston by the expanding gases.

4th. The Exhaust Stroke (Fig. 5).—When the piston has traveled about four-fifths² of its working stroke, the *exhaust valve* is opened by the cam on the two-to-one shaft³ to reduce the back pressure (or give *release*); the exhaust taking place during this fourth stroke of the cycle, or second return or in-stroke; the products of combustion being discharged from the cylinder, the gases which remain in the clearance space (or combustion chamber) mingling with the incoming explosive mixture of the next charge.

Thus, it will be seen that the *clearance space* (Fig. 2) is filled with the products of combustion at about atmospheric pressure when we commence to trace the working of the engine; and the piston, whilst it compresses the explosive mixture and makes the other strokes, with the exception of the explosion one (the third), is driven by the energy stored in the rotating fly-wheel.

Strangely enough, this method of working (the Otto Cycle) has never been equaled in efficiency by any other the mechanical genius of the world has been able to devise. Up to the time of its introduction, gas engines were worked by drawing in the charge during

¹ Refer to Article 26 for information.

² The time of opening the valve should vary with the piston speed, being earlier the higher the speed.

³ This shaft is shown in Fig. 1. It is connected with the crank-shaft by a system of tooth wheels, which make the cam-shaft rotate once, whilst the motor-shaft rotates twice; thus the exhaust valve opens once during every two rotations of the crank-shaft.

the first portion of the stroke, and then firing it, the work being performed during the remaining portion of the stroke¹; but the real and fundamental improvement made by Otto was the compressing of the contents of the cylinder (the explosive mixture) into the clearance space at the end before the charge was fired. This cycle of operations was new and original, and was founded upon true mechanical principles. The mode of working is not only admirable when examined from a mechanical point of view, but there is also the positive and direct gain of dealing with a compressed charge, instead of one at atmospheric pressure² (the engine acting as its own compressing pump); for the advantage of being able to start at the instant of explosion with the compressed contents of a whole cylinder full of explosive mixture, instead of the uncompressed contents of half a cylinder, is evident to ordinary apprehension. Then it is also claimed that the residue of the products of combustion remaining in the cylinder (the contents of the clearance space) acts as a cushion to moderate the effect of the explosion upon the working piston.³

If we are to maintain, in explaining matters, something approaching a sequence, it will be convenient to now give a little attention to the valves of the engines.

VALVES

7. In the previous article we have explained how the *inlet* or induction valve (called *automatic inlet valve*,

¹The Lenoir engine, patented 8th February, 1860.

²In recent years there has been a marked increase in the pressure to which the charge is compressed in gas engines, with a corresponding increase of efficiency.

³There is much to be said for and against this practice. A fresh mixture of gasolene vapor and air does not easily mix with the burnt gases; probably stratification more or less occurs. We shall further touch upon this matter in connection with *governing*.

and abbreviated to A.I.V.) is automatically opened by the suction action of the piston in the first stroke, being just kept on its seat at other times by the action of a weak spring;¹ on the other hand, we have seen that the exhaust valve was *mechanically operated* or lifted by a cam fixed on the *half-speed* or two-to-one shaft, the valve being spring closed. Now the automatic working of the inlet valve, although simple, and, under ordinary conditions of working, very effective, is not scientifically sound, particularly for high speeds, as the clearance space at the commencement of the first stroke is full of the burnt gases above atmospheric pressure, due to the back pressure from the silencer; therefore, when the piston begins its suction stroke, these gases have to expand before the fresh mixture can be drawn in by the piston; hence the sluggish action of the valve in opening, just when it should be promptly responding to the invitation to move given by the piston when it commences its stroke; indeed, in high-speed motors the valve should have a slight *lead*—that is, should open just before the commencement of the stroke, thereby facilitating the *scavenging*²

¹ This spring must be perfectly adjusted, for correct working. If too weak, the valve will not close rapidly enough to prevent the escape of explosive mixture on the commencement of the compression stroke, and will subsequently close with violent impact on its seat; with such a spring the motor might be run very slowly, but it would be quite useless for high speeds. On the other hand, if the spring be too strong, it does not allow the valve to open readily enough, or to its full extent, to allow a full charge of mixture to enter, and the power of the motor is therefore reduced. A common practice is to arrange the spring so that an air pressure of one pound per square inch will open it, but to get the best results the tension of the spring should be made adjustable. Spare springs are usually supplied long enough to allow them to be cut away bit by bit till the valve closes with a light beat.

² Sweeping out some of the residual burnt gases from the previous charge, and thereby allowing a greater quantity of mixture to enter the cylinder every charge, and in so doing increasing the power of the engines.

of the combustion chambers (clearance space). Moreover, the effect of the inertia of the valve becomes more pronounced as the speed of the engine increases, and the volume of intake suffers, whilst the metallic noise of the valve beating on its seat is objectionable. So, primarily for these reasons, makers have for some time, in increasing numbers, been fitting motors with *mechanical operated inlet valves* (abbreviated to M.O. I.V.), or worked in the same way as the exhaust valves from a half-speed shaft.¹ This enables the time of opening and closing of the valve to be arranged with mathematical precision, and (should it be thought desirable) the valve to remain open a shade after the piston commences the compression stroke, so that the momentum of the entering mixture may slightly add to the charge, before the piston on its change of stroke has converted the slight vacuum in the cylinder to a pressure above atmospheric.

In strictly examining the relative merits of these two arrangements, we ought to take into account the efficiency of the carburettor that is used in conjunction with each; but for our present purpose it will suffice to point out that in the M.O.I.V. a continuous flow of mixture can be relied upon for a definite movement of the piston, if the carburettor is capable of satisfactorily carburetting a sufficient quantity of air to keep pace with the protracted draw upon it, due to the longer time the valve remains open, as compared with an automatic one, for the latter cannot leave its seat till the vacuum in the cylinder is good enough to cause the spring to extend; the valve then suddenly opens, when a considerable inrush of mixture occurs, but the valve does not remain unclosed during the completion of the suction stroke, but rapidly flutters or pulsates on and off the seat (in a way everyone can understand who is familiar with the behavior of springs) till the end

¹In some motors the same shaft operates both valves, but the more general arrangement is a separate shaft each side of the engine.

of the stroke is reached;¹ consequently the demand on the carburettor is intermittent, and therefore less exhausting than in the other case.

Makers have from time to time, in acceding to the demand for mechanically operated valves, met with a good deal of trouble before they have reached satisfactory results; but the conditions which must be satisfied are so well understood now, that there is no difficulty in producing engines fitted with mechanically operated valves that are highly efficient, and are connected to carburettors adapted to their peculiar needs. Such valves are made interchangeable with the exhaust valves; they never stick or become sluggish in working through oil or other foreign matter clogging the valve or its stem, and with them the engine at slow speeds is more easily controlled, their use involving a mere repetition of the cam gear required for the exhaust valve.

Of course this slight complication is not in their favor, but in the best cars the design and workmanship are so excellent that they give no trouble; indeed, this is a case where some sacrifice of simplicity can be safely made for increased efficiency and flexibility.²

8. Leaky Valves.—A fruitful source of trouble and loss of efficiency in the gasolene motor is leaky valves. The burning and erosive effect of the hot gases (particularly if an exhaust valve has been held off its seat by dirt), and hammering of valves on their seats, must sooner or later lead to a sensible amount of wear occurring, both on valves and seats, even when the materials are just as perfect as it is possible to make them; but this legitimate wear is greatly increased in cases where the materials are too soft, or are in some other respects unsuitable. Of course, if this wear took place with

¹This action causes the actual working area to be only about half what it would be if the opening remained constant, so that the A.I.V. is larger than a M.O.I.V.

²Some engineers, whose opinions are entitled to respect, prefer, on the whole, the A.I.V.

absolute uniformity, without the surface departing from its true form, there is no reason why leakage should occur, but in practice, after a certain amount of wear, all valves leak, it being only a matter of degree; indeed, should the power of the motor diminish, and there is reason to suppose that it is due to leaky valves, the valves should be examined, and if there is any doubt about an inlet one, the spare valve (which should always be carried as part of the equipment) should be put in to replace it, and the old one can be examined and reground, if necessary, at home. The effect of leaky valves is at once felt, as during the compression stroke the mixture is forced through them, so that there is a smaller charge, and a full pressure cannot be reached.

9. **Grinding in Valves** is an operation that had better be left to the trained mechanic to perform, but cases occasionally occur where one is not available, and many owners of cars like to be able to do these little jobs themselves, or at any rate to know how they are done. So a few words relating to them will not be out of place. Now, if the valve is merely inclined to stick, it should be well washed out with gasolene, which will clear it of any bad oil or dirt. If, on the other hand, it requires grinding, it will be found that the conical or mushroom valve has a groove cut on its upper part to fit a screw-driver, or screw-driver bit that can be worked with a drill brace. The grinding material is a paste made of oil and fine sharp emery powder,¹ and the seat of the valve should be smeared with this, and the valve turned to and fro on its seat with the screw-driver or brace, being taken off occasionally and the face re-smeared to prevent grooving. This tedious operation must be continued until both surfaces present a bright and even appearance, without inequalities past which gas could escape. A piece of cotton waste should be

¹ Meteoric Knife Polish is a preparation of emery powder, and will do.

carefully placed to prevent any of the powder or dirt getting into the cylinder.

10. **Valve Lifter.**—To enable a motor bicycle to be freely pushed along or pedaled when the engine is not working, it is necessary to open the exhaust valve to prevent the motor being converted into an air-compressor, for, obviously, a good deal of work would have to be done by the cyclist on the machine in giving motion to the piston during the compression stroke.¹ So, to obviate this, motor bicycles are fitted with a device called a *Valve Lifter*, by means of which the exhaust valve may be kept permanently lifted at the driver's will. This fitting enables him to start the engine by walking the bicycle and suddenly letting go the lifter after the fly-wheel has had given to it enough momentum to perform the compression stroke. Skillful use of this lifter when on down grades will have a cooling effect on the cylinder (which often tends to become too hot for satisfactory working), cool air² being drawn into the cylinder through the exhaust pipe from the muffler each two revolutions of the engine. The only objection to this convenient expedient is, that the air in passing through the muffler tends to carry with it any dirt or dust that may be in it.

When using the lifter, care must be taken to cut off the spark, or explosions will occur in the muffler.

We may now proceed to describe the nature of the explosive mixture, and how it is produced ready for use in the cylinder.

CARBURATION AND CARBURETTORS

11. If the odor of escaping gas be detected in a house,

¹ Of course, the whole of this work is not lost, as some of it is recovered during expansion.

² After the engine has been running the muffler becomes very hot, and therefore the first few charges of air which pass into the cylinder when the lifter is used are warmer than the outside air.

it is proverbial that the ordinary householder will seek for the leak with a lighted candle, too often with a result that everyone has heard of and no one seems to profit by. In such cases the escaping gas mingles with the air in the room and carburates¹ it, as it is called; that is to say, the carbon and hydrogen of the gas, of which it nearly wholly consists, become rapidly diffused in the air, the oxygen of which forms, or tends to form, with the hydrocarbon gas, an explosive mixture which only requires igniting to cause an accident.²

Now the explosive mixture we use in the gasolene motor consists of air carburetted by the vapor of gasolene,³ and the apparatus used to prepare or form this mixture is called a carburettor, a fitting that appears in a great variety of forms; indeed, a month rarely passes without the pages of our admirable motor journals being adorned with some new device, which more or less differs from existing ones. There is nothing astonishing about this when it is understood how easily a mixture can be made, for everyone has noticed how quickly a little Eau de Cologne vaporizes when applied to the hands or face. The same thing occurs with gasolene; it is an exceedingly volatile spirit, rapidly evaporating, as all spirits do when exposed to the air, and this action is much increased by the application of heat, but it does not require any *preliminary* heating

¹ When air is impregnated with carbon, it is said to be carburetted or carburized.

² It is instructive to note that a mixture of this kind may be either too weak or too strong to explode, as for complete combustion about 6.3 *volumes* of air to 1 of gas are required; but the range of ignition appears to be about 1 of gas to 5 of air, to 1 of gas to 13 of air. And so, in the cylinder of the motor, we may have a charge which consists of too much air, or, the more usual case, one that has been super-carburetted (one that is too rich in gasolene vapor). Between these extremes there is a particular or critical mixture that in any case will be more efficient than any other, as we shall directly see.

³ Gasolene is a hydrocarbon. Refer to article on fuel, page 28.

for use in even the smallest engines. It can be readily vaporized by the simplest and crudest form of carburettor, and this principally accounts for the wonderful flexibility of the gasoline motor; indeed, it now appears difficult to make a motor that won't go, although a few years ago, when so many were commencing to experiment with motors who were unacquainted with matters relating to carburation and ignition, much trouble was experienced in coaxing them into motion.

If an explosive mixture can be readily produced, it is not such an easy matter to satisfy all the important conditions, for a satisfactory carburettor¹ must be capable of regularly supplying a perfectly adjusted mixture of gasoline vapor (or atomized spray) and air to the motor cylinder under all conditions of speed, load, and temperature; it must be self-adapting, and be able to automatically and definitely carburet the air to form a mixture of an exactly predetermined degree under all conditions of working. The very perfect speed control, over a wide range, of some of the best known motors is largely due to these conditions being more or less satisfied, and to a well-governed throttle² and an adjustable ignition.³

12. The Float-Feed Carburettor.—The type of carburettor that has survived all others, owing to its simplicity and absolute automatic action, is the *float-feed* one or *spray* kind, shown in Fig. 6, which shows the principal features of the class of carburettor to which it belongs. An *atomizing nozzle* N (whose size is care-

¹ Most carburettors on large cars are fitted with hot jackets for use in cold weather, as will be explained, the heat of the engine itself sufficing in other cases.

² When a motor is governed by *throttling or reducing the quantity of the charge* of the explosive mixture, without altering the proportions of air and vapor, it is said to be governed on the throttle. Refer to article on governing and controlling by throttling the mixture, page 55.

³ Refer to article on Advancing and Retarding Ignition, page 50.

fully calculated) is supplied with petrol from the *float-chamber* FC, into which the spirit (gasolene) flows by gravitation from its tank through the pipe X, and is kept at a *constant level* by a float FF, the needle

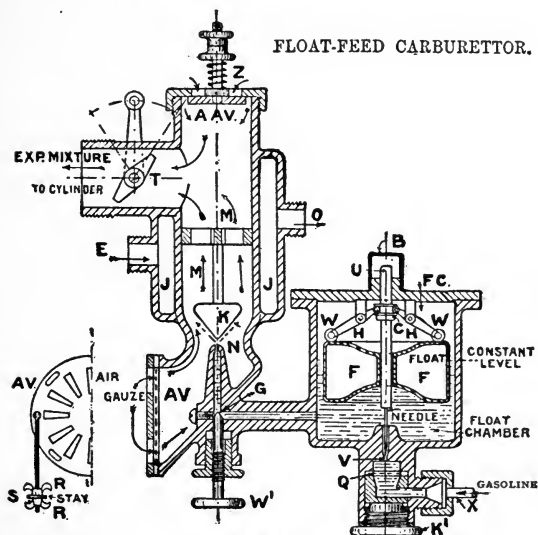


Fig. 6.

valve V regulating its flow; thus the gasolene is drawn from the float-chamber through an exceedingly fine orifice in the nozzle N, in the form of a spray, into the mixing chamber MM (pulverization being assisted by it impinging upon the roughened surface of the fixed cone K and becoming atomized), where it is carburized by mingling with the air from the inlet AV on its way

to the cylinder, the mixture being drawn through the throttle valve T (as it passes to the inlet valve of the engine) by the suction stroke of the piston. Vaporization of the atomized spray in the mixing chamber MM is assisted by the hot jacket J, which is heated by passing through it (entering at E and passing out at O) either hot water from the cylinder jacket or exhaust gases.¹

The *richness of the mixture* is regulated either by controlling the quantity of the gasoline passing through the nozzle N, or the quantity of air entering the mouth AV; if by the former, a valve G, operated by a hand wheel W', varies the size of the passage through which the gasoline flows on its way to the nozzle N; and, if by the latter, a shutter AV fitted with a sheet of gauze to prevent any fluffy matter passing (regulated by the fly nuts RR, the stay S being fixed), controls the quantity of air entering. This adjustment is made before starting on a run, to suit the condition of the atmosphere; the quantity of air required to make the best mixture varying with its temperature and pressure, it frequently happens that on a hot day the mixture will require readjusting in the cool of the evening. Now to keep the quantity of mixture constant, and to ensure the

¹The well-known Longuemarre carburettor is heated by the exhaust gas. In either case, the flow of fluid through the jacket should be regulated by a cock or plug, as when too cold, the gasoline does not volatilize sufficiently, and when too hot it does so to excess. As a matter of fact, it is only when the atmosphere is heavily charged with moisture, or when running through keen, frosty air, that a heating jacket is required; if such means for regulating the temperature of the jacket are not provided, the resultant cylinder charge is often much richer than is necessary or good for the engine, causing the plugs and valves to become sooty. When a hot jacket is not used on a carburettor, it is usual to so fix the latter that the air mouth is near enough the cylinder for the air entering the carburettor to be previously warmed; indeed, long, cold pipes should never be used to convey the mixture from the carburettors to the cylinder, as the gasoline vapor in the mixture is apt to condense when reduced in temperature.

opening of gasolene valve G and air-shutter AV, the level of the gasolene in the float-chamber FC must be unvarying, and this condition is satisfied by the action of the float¹ FF and needle, for should the level of the spirit slightly fall, the float FF and attached needle would descend with it, allowing the weights WW to operate the levers WH, whose fulcra are at HH. This movement causes the other ends of the levers to move upwards and carry with them the grooved collar on the needle, into which they fit; this lifts the needle point off its seat and allows more gasolene to pass from the tank to the float-chamber; this in its turn lifts the float and depresses the needle closing the valve, so that the float automatically maintains the level of the gasolene. Great care must be taken to pass the spirit through a strainer in filling the tank. In the best arrangements a screen of fine gauze is placed, as at Q, to exclude any dirt which may be in the gasolene, which, if allowed to enter, would tend to stop up the small passages, and prevent the flow of gasolene; indeed, such stoppages are a fruitful source of trouble, particularly at the nozzle, where dust, carried in by the air, is apt to give trouble.²

Should the screwed bung which is generally used to stop the filling-hole in the gasolene tank get lost, it should never be replaced by a cork one, as cork-dust sooner or later will find its way into the carburettor, and cause endless trouble by blocking the small passages.

13. Auxiliary Air.—It would be interesting and in-

¹ If great care is not taken to make the float perfectly fluid tight, the gasolene will penetrate it and cause it to be "water-logged," as it is called; it then, of course, ceases to act as a float.

² The usual expedient in this case, if time will not admit of the carburettor being properly cleaned, is to push a piece of fine wire through the hole and twirl it round; this invariably answers the purpose, but tends to enlarge the hole and make the mixture too rich; so, to be on the safe side, carburettors should be periodically taken apart and thoroughly cleaned.

structive to go into all the points which must be considered in deciding how the degree of carburation should vary with different temperatures, atmospheric pressures, speeds and other conditions of running, but space will not admit of this, and it must suffice to point out that the practice, which is found to give excellent results with this type of carburettor in maintaining a *uniform mixture*, is to admit what is called *auxiliary air* to the mixing chamber (to mingle with the mixture and reduce its richness), when the engine is running fast and the vacuum is good. The air is admitted through the auxiliary air-valve AAV, which is fitted with an adjustable spring Z (so that its strength may be adjusted to give the best results), and when the suction is strong enough, this valve is forced open by the air outside, against the action of the spring, and extra air flows in and mingles with the mixture. Now, let us try and be clear why this extra air is required.¹ To do this, we must realize that during a rapid suction stroke, air and gasoline are being drawn through the openings AV and nozzle N respectively, at a high velocity; at the end of the stroke the inlet valve of the engine cylinder suddenly closes, and no further mixture can enter. This means that the flow of air through AV almost immediately stops; but not so the gasoline, as, due to its much greater density and inertia, it continues to flow into the mixing chamber M, and would make the mixture much too rich to give a good result in the cylinder were it not for the extra air entering by the auxiliary valve. Again, as the engine slows down, let us say, due to throttling (partly closing the throttle valve T), there is a greatly reduced suction (not enough to open the auxiliary air-valve), and although air may be freely entering at AV, the gasoline will be passing out of nozzle N in a very sluggish way,

¹In some carburettors, instead of admitting air by an auxiliary valve, it is passed into the mixing chamber by increasing the opening of the air inlet at AV by a control arrangement.

and there will be an abundance of air in the chamber to form a proper mixture, until at a critical speed of the engine the suction will not be strong enough to draw gasolene out of the nozzle, as the normal level of the spirit in the nozzle must always be a little below the orifice; but this speed of course the motorist soon becomes familiar with, and he is careful to avoid touching it if he wishes to keep the motor running.

Formerly (in the days of the old cut-out governor) it was not practicable to vary the speed of the engine very much, but with the introduction of the *throttle control*¹ which has been so generally adopted, a great amount of elasticity or flexibility in running became possible, and now most engines have a range from about 200, or even 150 revolutions per minute when throttled, to 1500 or 1600 in some cases when the throttle is fully open, the amount of mixture used being almost in proportion to the speed.

In many of the carburettors in use (notably Kreb's), great ingenuity has been displayed in devising them, so that the fundamental condition for perfect working may be automatically satisfied, namely, *the production of a constant degree of carburation at all speeds, so that the power of the motor may be directly proportional to its speed*. In those carburettors that are not fitted with such an automatic arrangement, the mixture must be made by hand. In any case, the adjustment should be made to enable the carburettor to take in as much air as it possibly can whilst producing a good mixture, as a faulty mixture is nearly always due to an extravagant and wasteful use of gasolene, with all the evils attending it.²

The spray type of carburettor, largely owing to its compactness and the small amount of room it takes up, is also superseding the float type for motor cycles,

¹ By the *governor*; or the amount of mixture entering the cylinder may be controlled by hand.

² Generation of steam in the cylinder jacket, sooty plugs, loss of power, and waste of fuel.

although it has the disadvantage of being easily flooded when the machine is run over a rough road, the jolting allowing the gasolene to escape into the reservoir each time the needle is bumped off its seat; as a result, the gasolene supply-pipe has to be fitted with a small cock or valve, so that the quantity flowing can be regulated by hand when necessary.

In starting, it is sometimes necessary (owing to the nozzle becoming more or less closed by dirt, and the gasolene in it becoming stale¹ by standing) to flood the carburettor and to assist in forming a rich mixture by spraying the spirit by hand; to do this, the thimble B (Fig. 6) is taken off, and the end U of the valve spindle moved up and down, an upward movement allowing the gasolene to enter the float-chamber from the tank, and a push downwards forcing it through the nozzle.

14. Surface Carburettors.—The carburettors that were first generally adopted, and are still used on some motor cycles, were of the surface type, an example of which, of the pattern used on motor tricycles,² namely the De Dion, is shown in Fig. 7. Outwardly it consists of a triangular brass or copper box, shaped to fit between the tricycle frame tubes and the rider's seat. In the figure, one side has been removed to show the arrangement of the interior; a plate D, fixed to the air-tube or chimney AT, divides the whole box into two parts, the lower forming a reservoir for the gasolene, a further quantity of which is generally carried in a cylin-

¹ Gasolene, when allowed to stand exposed to the air, rapidly evaporates, the most volatile part passing off first, the portion remaining being impoverished or stale.

² The principle of the surface carburettor can be best understood by examining this pattern. Those used on bicycles are very much alike in principle and general construction. In a pattern largely used the air-tube AT is carried down nearly to the bottom of the reservoir R, and its lower part is perforated or zig-zagged, so that the air bubbles up through the spirit instead of skimming its surface, and with this arrangement almost the last drop can be used, even if it is a little stale.

drical tank attached to the rear frame of the machine, and placed just above and connected to the carburettor by a pipe. The plate D is used to prevent the spirit splashing into the upper chamber X in the form of spray, instead of passing into it as vapor. The air enters through the air-tube AT, and passes between the

THE DE DION SURFACE CARBURETTOR.

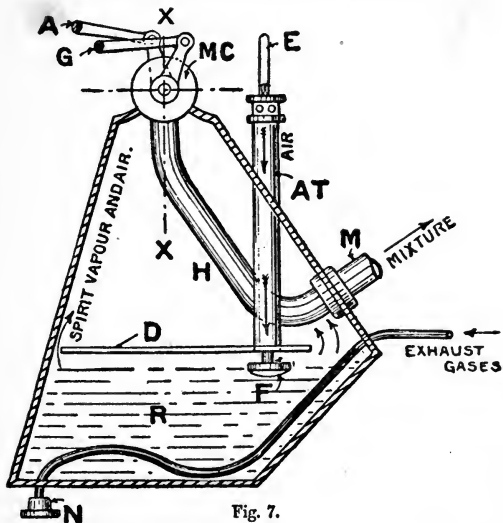


Fig. 7.

plate D and the gasolene surface (which in starting is just below the plate) as shown, licking the surface, and carrying with it a charge of spirit vapor to the chamber X, on its way to the *mixing chamber* or *twin tap*, MC. The function of the tube AT is to admit air below

the plate D during the suction stroke of the engine,¹ so that it may be diffused in the gasolene vapor, as explained, and be drawn through the twin tap MC, which is arranged to admit an adjustable quantity of additional air to form a suitable mixture to enter the cylinder through the pipe M. A bent pipe, LN, from the engine exhaust passes through the lower part of the reservoir to warm the gasolene, and to accelerate its vaporation, as evaporation of the spirit lowers its temperature. F is a float fixed to a wire EF, which passes through the air-tube AT, the length of the wire at E projecting above AT indicating the level of the gasolene in the reservoir. The most interesting and important feature of this type is the *twin tap* MC, shown in detail in Figs. 8, 9, and 10, the Fig. 8 showing a section on line XX (Fig. 7), and Figs. 9 and 10 being sections taken through the lines DD and EE (Fig. 8) respectively. These show how the *air* lever A is connected to a hollow cylindrical part, a half of it, MON, being made of wire gauze, in such a way that a movement of lever A controls the quantity of rich mixture entering below at K from the chamber H, and the amount of auxiliary air passing in from above at J, the two streams mixing in the chamber P to form the perfected mixture, which passes into the pipe M on its way to the cylinder. A movement of the lever A (Fig. 10) to the right increasing the opening for air, and decreasing the opening VN for the rich mixture, so that the quality of the mixture can be regulated when starting to give the best results for the gasolene used, and the temperature, pressure, and condition of the atmosphere.

The Figs. 8 and 9 show how the gas lever G moves the hollow cylinder WY, which is free to revolve in the outer cylindrical case, so that it acts as a *throttle valve*, giving the rider control over the *quantity* of mixture which passes into pipe M from the mixing chamber P on its way to the cylinder.

¹The cap on top of AT forms an adjustable shutter, used to regulate the quantity of air entering.

One of the drawbacks of this carburettor is that it takes up more room than the spray one, and it cannot

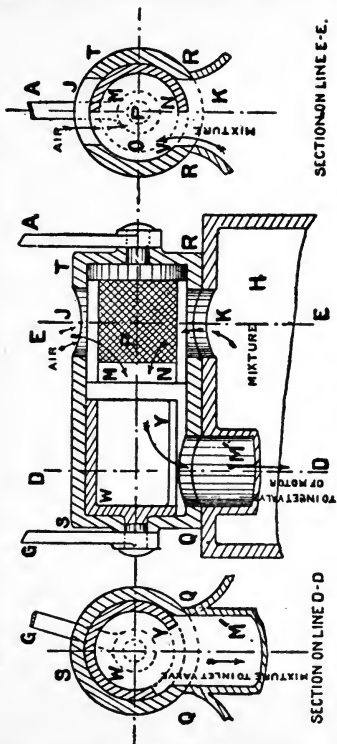


Fig. 10.

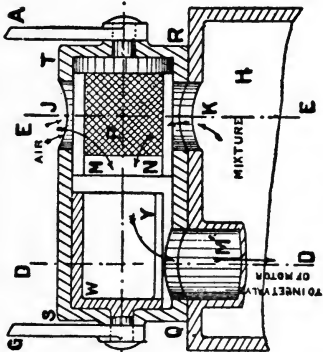


Fig. 9.

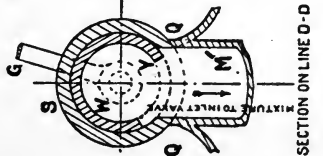


Fig. 9.

be used with such heavy gasoline as the latter can. On the other hand, it has some advantages which perhaps

have not always been appreciated as they should be for small engines, particularly for motor bicycles. Not the least of these is, it has no very small gasolene holes to get clogged with dirt, and throttling does not affect the carburation, as it does in many of the simplified spray carburettors, leading to excessive gasolene consumption.

THE FUEL

15. The fuel that is almost exclusively used by motorists in this country is the light petroleum spirit, called gasolene. It possesses valuable properties, which, notwithstanding its drawbacks, make it at present considered the most suitable fuel for motor purposes. It is a distillate of crude petroleum, the various products of which (called fractions or cuts) are obtained by what is known as fractional distillation.

16. **Straining and Filtering Gasolene.**—Comparatively few motorists realize the necessity of carefully straining the gasolene as it is poured into the supply-tank of the car. If they commence by using a strainer, sooner or later it will become mislaid, and the spirit is poured into the tank direct from the can; in doing this, they risk getting an accumulation of dirt in the tank, which in due course finds its way into the carburettor, with the inevitable stoppage, for, even if the carburettor is fitted with a disc of gauze within the union below the float-chamber, as shown at Q in Fig. 6, it is only a matter of time for its minute interstices to become completely filled, and the flow of gasolene to be stopped, so, should the strainer become mislaid, one should be improvised. For instance, a clean handkerchief folded three or four times has been found to be an effective substitute. Many motorists have been troubled by a kind of short silky fluff getting into the union below the float-chamber; this stuff is much too fine to be arrested by the gauze, so something with a much finer mesh is required for the strainer; a good-sized piece of

clean thin chamois-skin has been found effectually to filter the spirit without unduly delaying the filling of the tank; of course this necessitates the use of a funnel of large diameter, say some 8 or 9 inches at least.

GASOLENE, ITS DISADVANTAGES, AND THE PRECAUTIONS TO BE TAKEN IN USING IT

17. No one should be entrusted with a can of gasoline who is unacquainted with some of its properties; every motorist should make a point of learning what liberties he may and may not take with it. It being a highly volatile spirit, a naked light or ordinary lamp should never be taken into a place where it is stored, or into a motor-house; nor should smoking be allowed in such places, as a slight leak would probably lead to an accumulation of gasoline vapor, which would be highly dangerous. On the other hand, leakage of gasoline on a moving car would cause no more danger from explosion than a gas jet escaping for a few minutes in the open air, but a fairly large quantity of gasoline spilled in the street or in a room would be a cause of danger from its vapor mixing with the *air* and forming an explosive mixture, through which a flame could leap several feet. Gasoline spirit itself merely ignites with a hot flame, and does not cause an explosion; indeed, a poker almost red-hot may be placed in gasoline without its igniting, although a white-hot one would cause it to burn; but when gasoline vapor mixes with about 8 to 10 times its volume of air, a rich gas is formed, which will burn without exploding; a larger proportion of air, about 17 or 20 to 1, forms an explosive mixture. Finally, it is dangerous for transport or storage, and the risk is greatly increased in a hot climate, owing to its low flash-point, as any oil is dangerous when heated above its flashing-point, be that high or low. Of course the ideal light for the motor-house is the electric light,

but when this is not available a Davy lamp¹ should always be used when gasolene is under cover, to avoid risks, as the conditions necessary for an explosion should be assumed to always exist.

18. Objectionable Odor of the Exhaust Gases.—The offensive odor of the exhaust gases, from most gasolene cars, is causing a deal of unfavorable comment. It is bad enough for the perfume of the sweet-smelling brier in a country lane to be polluted by an occasional passing car, but in our streets and parks, with a succession of passing cars, the nuisance is becoming increasingly pronounced, and all who are interested in the future of the automobile should do their best to minimize it. It is mainly due to exhausting unburned fuel, and to the use of either an unsuitable lubricating oil in the cylinder, or one that may be very good for the purpose, but is being used in excess. The splashing of oil on the muffler, or on an air-cooled cylinder, or other hot part, will also cause this trouble. Briefly, the trouble is more likely to occur in engines (a) fitted with unjacketed carburettors; (b) with long and large pipes connecting the carburettor to cylinder; (c) at slow speeds than at high speeds; (d) in small cylinders than in large ones; (e) when starting, due to condensation of the spirit vapor in the cylinder, etc., and it is bound to occur whenever an unclean cylinder lubricating oil of too low flash-point is used.

19. Other Fuels than Gasolene.—The only other fuels that could be economically employed in internal combustion engines of the motor type are *benzol* or *benzene*, a spirit distilled from coal-tar, and technical or denatured alcohol. Either of these could be used with a little modification of the valves, the carburettor, and the compression, and either would appear to be a cheaper fuel.

¹ This lamp is surrounded by wire gauze, so the explosive gases, though they pass free through the meshes, are so cooled by contact with the comparatively cold metal and by its high radiating powers, that though they may be burning on one side of the gauze, the combustion ceases as the gases pass through. **NOTE**—Gasolene vapor is heavier than air.

20. Air Required for Combustion.—We have seen that when a charge of mixture, of gasolene vapor and air, is exploded in the cylinder, rapid combustion or burning of the gas occurs, the evolution of heat occurring as it burns and expands, causing the piston to be pushed forward with great force. We must now be clear about the elementary chemical conditions which must subsist, if the *chemical combination* which causes the explosion is to be perfect. Now, by chemical analysis it is found that gasolene (hexane C_6H_{14}), of specific gravity 0.700, contains 84 per cent. of carbon and 16 per cent. of hydrogen, and by the aid of chemical equations we can deduce the proportion of air required to supply oxygen enough to mix with these gases, in order that when the mixture is ignited it may burn so rapidly¹ as to produce a sharp explosion, no gas remaining unburnt. Thus 1 lb. of hydrogen (H) requires 8 lbs. of oxygen (O) to burn it (the product of combustion being steam), and 1 lb. of carbon (C) requires $2\frac{3}{8}$ lbs. of oxygen to burn it to carbonic acid (carbonic dioxide, CO_2). But the composition of air by weight is one of oxygen to $3\frac{1}{2}$ of nitrogen (N) nearly, so for each pound of oxygen required $4\frac{1}{2}$ lbs. of air must be provided. Then to burn 1 lb. of gasolene we must have $.84 \times 2\frac{3}{8} \times 4\frac{1}{2} = 10.18$ lbs. of air for the C, and $.16 \times 8 \times 4\frac{1}{2} = 5.76$ lbs. of air for the H, or $10.18 + 5.76 = 15.94$ lbs. in all. But if we had taken the more exact proportion of N to O in the air, this would have amounted to nearly 15 lbs. to burn 1 lb. of gasolene. And as there are 13.14 cubic feet of air to the pound, at a temperature of $62^\circ F.$, we get $15 \times 13.14 = 197$, as the quantity in cubic feet chemically required. Then we must not forget that the hydrocarbon fuel is being

¹The rapidity depends upon the pressure reached during the compression stroke. This law applies to all explosives. Nobel found that a pebble of gunpowder, which took two seconds for its combustion in free air, was burned in about one two-hundredth part of a second under pressure in the barrel of a gun.

burnt in the cylinder in presence of nitrogen, and some of the products from the previous explosion. So it is usual to allow about twice the theoretical quantity, or 30 lbs., of air to completely carburate 1 lb. of gasolene. If space permitted, it would be instructive to examine under what conditions of temperature, pressure, and proportions a combustible gas combines completely with oxygen, but as a matter of practice in running, *the most economical mixture* to be used in the cylinder of a motor is usually determined by trial at average speed, the carburettor being adjusted to give the best results, without the exact proportion of air and gasolene vapor passing through it being known.

22. **Horse-Power.**—In speaking of *power*, we must be careful to distinguish it from the term *force*, as the two words are not synonymous. The former term was very loosely used by the older writers on mechanics when referring to force; but *power*, it should be understood, *is the rate of doing work*, that is to say, if we are to measure work we must know the amount of *work* done *in a given time*, then the quotient $\frac{\text{work}}{\text{time}}$ equals the power.

The unit of power was fixed by James Watt, who found, by experiment, that the maximum amount of work a powerful dray horse could do when pulling regularly at a slow speed for eight hours a day, was at the rate of 33,000 foot-pounds per minute.¹ Hence one horse-power=33,000 ft.-lbs. per minute.² So to determine the *horse-power* (usually abbreviated to H.P.) of any motor, we have simply to *calculate in foot-pounds the work done by it in one minute, and divide by 33,000.*

But we must decide first whether we wish to measure the power of the motor to do work outside itself, the

¹ It is well known that the *ordinary* draught horse is not capable of doing more than about 22,000 ft.-lbs. per minute, or about two-thirds of the standard amount.

² The French *force-de-cheval*, or metric horse-power=75 kilogram-metres per second=542.48 ft.-lbs. per second, or 0.986 the horse-power,

effective power available to drive the car through the gear, or do work in overcoming the friction of a clutch or brake applied to its fly-wheel, which is called *brake horse-power* (B.H.P.);¹ or, on the other hand, whether we are to measure the *indicated horse-power* (I.H.P.), the power developed in the cylinder of the motor by the varying pressure of the expanding gases acting on the piston, called *indicated*, because an instrument known as an *indicator* is used to declare or indicate the variations in the pressure on the piston, from which the mean pressure can be easily found, and this, multiplied by the distance in feet per minute the piston travels in doing its *working strokes*, and divided by 33,000, gives the *indicated horse-power*.

23. **The Mechanical Efficiency of the Engine** takes account of all the frictional resistances, and compares the work given out by the crank-shaft with that done in the cylinder.

Thus, mechanical efficiency = $\frac{\text{brake horse-power}}{\text{indicated horse-power}}$, the value of the quotient varies; it decreases somewhat as the size of the engine becomes very small, and also decreases in any given engine as the power at which it is being worked is reduced much below that which it was designed to develop; this is due to the fact that its frictional resistances are somewhat less at full power than at any lower power, although, of course, they increase with the power, but not quite in the same proportion. Thus a 20 horse-power motor (if well designed for that power) would probably give 17 horse-power at the brakes, and would therefore have a mechanical efficiency of $\frac{17}{20} = 85$, or 85 per cent.,² but the same en-

¹The brake horse-power is measured by using a friction brake or *dynamometer*. It is the power *some makers* refer to when advertising their cars. There is a marked want of uniformity in accurately defining the power.

²A good average result. When working under favorable conditions, this efficiency varies from 90 to 70 per cent., that is to say, from 10 to 30 per cent. of the full power developed in the cylinder (the indicated horse-power) is lost.

gine throttled down to 5 horse-power would probably not give out more than 2 H.P. at the brake, and would have a mechanical efficiency of $\frac{2}{5}=0.4$, or 40 per cent.

This shows what has to be paid for the luxury of driving a car that is powerful enough to negotiate hills at a high speed, and is running at other times much below its full power.

24. Fuel Efficiency of the Engine.—We have remarked (Article 21) that few motors running have a *heat* efficiency as high as 25 per cent.; probably 20 per cent. is nearer the mark the best cars reach when running at their highest efficiency. And, if we assume their *mechanical efficiency* to be 75 per cent., and take the product of these quantities, namely $\frac{20}{100} \times \frac{75}{100} = \frac{15}{100}$, we get 15 per cent. of all the energy of the fuel given out in the form of work by the crank-shaft.

Now with this data before us, we will see what power should be developed at the crank-shaft if we are using a gallon of 0.680 gasolene per hour when running. A gallon of this spirit will weigh 6.8 lbs.,¹ and we have seen (Article 21) that the heat units in one pound of gasolene ²=20,748, therefore the number in one gallon=6.8×20,748=141,086.4 B.T.U. (equal to 141,086×778 ft.-lbs.), and therefore the *brake horse-power* = $\frac{15(141,086 \times 778)}{100(60 \times 33,000)} = 8.315^3$; so, on these assumptions, the horse-power a motor that is burning a gallon of

¹ The weight of a gallon of liquid is found by multiplying its specific gravity by the weight of a gallon of water (or 10 lbs.), so 0.680×10=6.8 lbs., which is the weight of a gallon of 0.680 gasolene at 59° F.

² In article 21 we referred to gasolene of specific gravity 0.700, but so long as the ratio of H to C remains constant, the theoretical thermal value *per lb.* is the same for all densities.

³ This is the power given out at the crank-shaft. There are further losses in transmitting it to the road wheels, as we shall see.

gasolene an hour can be expected to give out is an average of $8\frac{1}{3}$, nearly equivalent to $\frac{8.315 \times 100}{75} = 11.08$, say, 11 indicated horse-power.

As some cars run 30 miles (at about 20 miles per hour) on a gallon of gasolene, it follows that their brake horse-power and indicated horse-power can very little exceed an average of $\frac{2}{3} \times 8.315 = 5.543$, and $\frac{2}{3} \times 11.08 = 7.386$ respectively.

Of course engines fitted with ball bearings have a higher *mechanical efficiency*, and give out a proportionately higher B.H.P.

IGNITION

25. There is no part of the gasolene motor of greater importance than the ignition apparatus, the slightest disarrangement of which invariably causes trouble, as every driver soon discovers, for he finds that most stoppages are due to something abnormal occurring to this all-important part. Of course, the function of the ignition apparatus is to ignite the charge of explosive mixture in the cylinder on or about the completion of the compression stroke, when the charge is at the maximum pressure due to compression, and a working stroke is about to commence. This ignition was formerly very generally effected by what is called—

26. **Tube Ignition.**—A small platinum tube, closed at one end, being fitted to the cylinder in the combustion chamber, the closed end projecting outside, and heated to incandescence by a blow-lamp of the Bunsen burner type¹ fed from the gasolene-tank, the mixture being forced into the tube and ignited each time compression occurred. It might be supposed that with this

¹There was some difficulty in keeping the lamp alight when the wind caught the car in certain directions, and the flame was apt to get deflected from the ignition tube, allowing it to cool down enough to cause late firing, with weaker explosion, and consequent loss of power.

arrangement the charge would be apt to ignite before the completion of the compression stroke (indeed, this pre-ignition does sometimes occur, accompanied by a peculiar sound, which if once heard is easily recognized), retarding the piston as it nears the end of its stroke, and putting a severe strain upon all the bearings; but by moving the lamp to another part of the tube, farther away from the cylinder, the time of firing can be retarded,¹ and this retardation made to vary the power and speed of the engine. Thus the singular synchronism of pressure and ignition, due to the mixture becoming rapidly more explosive as its pressure increases, is capable of being adjusted. Of course, should the valves be leaky, the compression suffers, and the mixture is not forced to the part of the tube directly over the flame (which would be more or less filled with the burnt gases from the previous stroke), the *timing* or moment of ignition being affected with constant reduction in power. Again, with this arrangement, if the lamp be adjusted for a certain speed, it is not right for a higher or lower one, but the arrangement has been made to give very good results on comparatively slow-running engines, with a limited range of speed. But the principal reason why tube ignition has practically died out is, the time of firing the charge was not variable at the hands of the driver. However, notwithstanding these disadvantages, a few cars are still so fitted as a reserve or stand-by, in case the electric ignition should fail, but even for this purpose it is doubtful if it will much longer survive, owing to the danger of using a naked light on the car. To the use of an *electric spark* to ignite the explosive mixture in gasoline engines at a moment which can be controlled by the driver, giving him command over a wide range of speed, not a little of the wonderful development of the motor is due, and we must now give some attention to—

¹ Another arrangement used to advance and retard the ignition is a nipple whose orifice can be regulated.

27. **Electric Ignition**, which is a great advance over the method just described, as, with it, greater compression is possible and there is absolute immunity against fire. Needless to say, the object of the electric ignition apparatus is to produce automatically a very hot electric spark (as blue as possible) in the midst of the explosive mixture, at or about the moment the working stroke commences. There are two systems at present in use—(a) the well-known *high-tension ignition*, involving the use of *induction coils*, with either *accumulators* or *batteries*, and (b) *electro-magnetic ignition*.

In the former the electric current is produced by what we may call chemical means, whilst in the latter system small dynamos or magnetos, driven by the motor itself, *mechanically* generate the current used for firing the mixture, but as they only work when the motor is running, the electric current required to start the engine has to be generated either by giving a certain speed to the engine, by working the starting handle, or the current for starting is supplied by an accumulator, which, when necessary, is recharged by the dynamo. On the other hand, these machines have many advantages, not the least important of which is freedom from stoppages due to short circuits and leakage; they also can be made to give a hotter spark than primary batteries and accumulators and are therefore more capable of causing complete ignition of a big charge, but, as at present made, their delicate construction makes them liable to give a deal of trouble. However, there are several types striving for supremacy,¹ and it is not possible to predict the ultimate issue; so, many makers and motorists are awaiting developments before making any change in their ignition arrangements.

Although the balance is in favor of the final form being of the electro-magnetic type, the *high-tension ignition* system, with accumulators and induction coils, pre-

¹There is sure to be some marked improvements and interesting developments in this direction before long.

viously referred to, still holds its own, owing to its simplicity and reliability, and, therefore, may be briefly examined, but the exigencies of space forbid the author doing anything like justice to it. Referring to Fig. 1, it will be seen that this electrical system consists of (1) the accumulator or battery, (2) the coil, (3) the commutator or contact maker and breaker, (4) the sparking plug, (5) the switch; and we may now proceed to describe these parts before attempting to explain how they must be linked up to form a complete system; so we may commence with—

28. The Battery, or Accumulator.—This is called a *primary battery* if it is so arranged that electricity is created by the chemical action of acid solution upon zinc and carbon plates, but if it consists of a series of lead grids or plates, some filled with a paste of peroxide of lead, forming the positive element, and others filled with pure lead in a finely divided or spongy condition forming the negative element, placed in a liquid-proof receptacle filled with water acidulated with sulphuric acid, it is an *accumulator* (or secondary or storage battery), which can accumulate or store¹ within itself a charge of electricity from a dynamo, or a primary battery of suitable construction. When discharged, both

¹ Strictly speaking, it does not actually store electricity. The lead plates and lead-peroxide, by means of a continuous current or charge from some outside source, are so changed that they become capable, owing to their chemical condition, of themselves creating a flow of electricity when the circuit is closed. The usual cells are of two distinct types—namely, the Plante, in which the active material is chemically or electrically formed out of the surface of the leaden conductor, and the Faure, in which the active material is formed into a paste, and is caused to adhere to a lead grid or conductor. The former type is superior for durability, but the latter has the great advantage of being much less expensive in manufacture. Most of the accumulators now made are one or the other of these types, only differing in constructional details. They all have a *very low internal resistance* compared with any form of primary battery. Some automobile makers now use accumulators fitted with Plante positive plates and Faure negatives for traction.

the positive, or lead-peroxide plates, and the negative, or spongy lead plates, are largely converted into lead sulphate. When being charged, the lead sulphate undergoes a chemical change, due to the electrolytic action of the charging current, which converts the positive plates once more into peroxide of lead, and the negative plates into spongy metallic lead. These two elements in the sulphuric acid solution give an electro-motive force of about 2.2 volts. Thus the accumulator creates electrical energy in the same sense as a primary battery does, *i.e.*, by chemical action, but is renewable, when exhausted, by passing through it a current of electricity from another source, in the opposite direction to that taken from it in discharging.¹

Accumulators are more generally used than primary batteries, for although they have not the same capacity (will not be efficient for so many miles) bulk for bulk, when properly used they have not to be replaced by new ones after they have become exhausted, as must be done with the latter.² As in both cases the method of using them and their function is the same, either can be used in this system of ignition, but for the reasons given we will assume that accumulators are preferred. Now, each accumulator is fitted with two terminals, called *positive and negative poles*, arranged so that

¹The life of the accumulator greatly depends upon the care taken in charging and discharging, and upon the purity of the materials used, and it is false economy to buy anything but the best cells.

²Primary batteries are usually *dry* ones, modifications of the simple voltaic elements, zinc and carbon, of constant or non-polarizable type, filled with some material to prevent the liquid electrolyte from spilling. A battery usually consists of four cells, and although the initial cost of these is far less than that of accumulators, and they are capable of standing rougher and more irregular treatment, they are not so economical, as their energy depends upon the consumption of the zinc plates, and when these have been used up, the cells are practically worthless, and must be replaced. So, for continual use, this makes them ultimately twice as costly as accumulators.

wires can be connected to them by means of set screws. If these terminals be connected by a wire (completing the circuit), electricity will flow from the positive to the negative terminal continuously, and in so doing will gradually discharge the accumulator. Electricity flows with very little resistance through all metallic substances, and with more resistance through water or across any moist or wet surface. If a wire carrying a current comes into contact with any metallic substance in more than one place, the current will divide between the two; in this case the wire is said to be short-circuited at that part. Therefore, in conveying current from one part of the motor to another¹ the wires must be (insulated) covered with insulating materials, those of an india-rubber nature being found most efficient. The higher the tension or pressure used to urge the current through the circuit, the thicker must the non-conducting cover be, for if the insulation be not sufficiently good, electricity may leak through the engine frame to the negative pole (*become short-circuited*, or *shorted*, as it is sometimes called). Now, the electrical current, as it is discharged from the accumulator, is not lacking in quantity (*amperage*),² but it is of too low *voltage*³ or pressure, and to get a current to pass, in the form of sparks, across the small insulating gap at the end of the sparking plug, the pressure must be

¹To reduce the resistance to a minimum, and avoid the chance of leakage, these connections should be as direct and short as possible, and great care should be taken in making them.

²The *ampère* is the *unit of current*, or the *unit rate of flow* of electricity; and the *ampère-hour* equals the ampère flowing for one hour.

³The volt is the *unit of pressure, electro-motive force* (E.M.F.), or potential difference (P.D.). The *unit of resistance* which the *conductor* offers to the flow of current through it is the Ohm, and $E.M.F. = \text{Amperes} \times \text{Ohms}$.

The *watt* equals the ampère multiplied by the *volt*, and the *watt-hour* equals the *energy expended in one hour by one watt*, which equals 3600 joules, or $3600 \times .7373 = 2654.28$ foot-pounds.

raised from that of the accumulator cells, viz., about 4.4 volts, to some thousands of volts; so, to transform it into the high-tension current necessary for this purpose, it is passed through an—

29. Induction Coil.—When the current flows from the accumulator, it is conducted through several turns of insulated wire (about 20 gauge), wound round a central core of soft iron wire. This is known as the “primary” or “low-tension” winding. From there it passes to a contact-breaker, which automatically opens and closes the circuit, and then flows back to the accumulator, so completing the circuit. Round this primary coil (but well insulated from it) is wound a second coil of *very many* turns of fine wire (about 32 gauge), the ends of which are connected to the terminals of the sparking plug. This coil is known as the “secondary” or “high-tension” winding. When the primary current flows, it magnetizes the iron core and the magnetic field established interlinks with the very many turns of the secondary coil; it also immediately attracts the iron armature of the contact-breaker, and so breaks the circuit. The magnetic field then disappears, and the spring of the contact-breaker pulls the armature back to its original position. This again completes the circuit, and the magnetic field once more interlinks with the secondary coil, and the whole operation is repeated in this way several times a second.

The magnetic field, in surging through the secondary coil of many turns, induces in it an electrical pressure high enough to break down the insulating gap at the sparking plug points, resulting in a discharge across it in the form of sparks, which ignites the explosive mixture in the cylinder. The power and efficiency of the coil is greatly increased by being fitted with a condenser, made up of a series of alternate layers of fine tinfoil and paraffined-waxed paper, the connections being so made that when the current through the primary winding is interrupted by the vibration of the trembler, the condenser acts as a “shunt circuit,” and stores up en-

ergy which would otherwise dissipate itself in a very destructive spark at the platinum contacts of the circuit-breaker,¹ and this stored-up energy helps the current to rise quickly in the primary coils at the next making of the circuit. The efficiency of the spark depends on the large number of turns in the secondary winding as compared with the primary turns, also on the rapidity with which the primary circuit is broken, and on the strong magnetic field of the soft iron core when temporarily turned into a powerful magnet. Another important detail of the system is the—

30. Contact-Breaker, or Commutator.²—This is generally of the *wiping contact type*³ as shown in Fig. 1, and consists of an insulated disc (usually made of fiber) fixed to the half-speed shaft. At a fixed point on this disc is a sector of brass connected directly to the shaft, which again is in metallic contact with the frame of the motor.

A metal *brush* or *collector*, insulated from the frame of the engine, and in metallic contact with one terminal of the primary coil, ordinarily rests on the insulated disc, and we shall explain directly what part this commutator plays in the complete system.

31. The Sparking Plug.—The principal features of the sparking plug or igniter are shown in Fig. 11, which

¹If an inefficient condenser be fitted a strong spark is obtained when the circuit between the platinum-pointed screw and trembler is broken, which quickly causes unsatisfactory working by burning away the contacts, necessitating readjustments and wasting current.

²The two terms contact-breaker and commutator are not synonymous, therefore they must be correctly used. A *contact-breaker* is fitted to a *single-cylinder engine*, and a *commutator* to a *multi-cylinder* one, though in both cases, types and designs may be precisely similar. In the latter case its function is to *commute* the current from one path to another, or, more explicitly, from one cylinder to another. In the well-known apparatus introduced by Mr. F. C. Blake of Kew, two or more cylinders are fired by means of a single coil with a high-speed trembler.

³The other type, which was formerly so much used, is the *spring-blade* or *trembler contact-breaker*.

represents the De Dion Bouton new pattern plug. Into a brass or gun-metal shell S (which is screwed into a cylinder wall, and is in metallic contact with it) a hollow non-conducting plug D, made of porcelain (or compressed mica), is held in position by the gland nut N, and through plug D a wire is fixed, the pointed end P being of platinum, and the other end E being in metallic contact with the brass cap C, on to which the insulated copper wire from the induction coil, carrying the high-tension current, is screwed by the brass fly-nut F, placing the platinum point P in metallic contact with the wire from the coil. The other platinum point Q is fixed in the brass shell S, so that PQ forms

SPARKING PLUG.

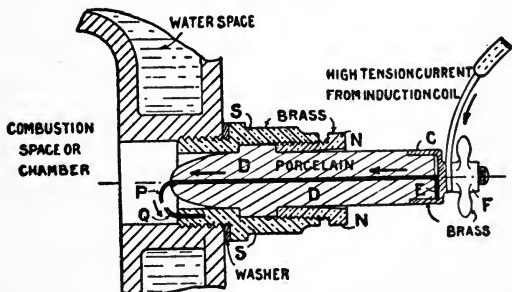


Fig. 11.

the spark gap, and we shall explain directly what occurs when the plug is in use.

32. External Plug Gap.—By introducing a second gap into the high-tension circuit, a spark can be maintained inside the cylinder under conditions which would otherwise prevent any effective ignition taking place, and contrivances have been introduced for attaching to the sparking plug, so that external sparks

can be obtained. This not only intensifies the spark, but assists in preventing trouble due to sooting of the plug, and enables the driver to see at a glance whether current is passing through each of the plugs; and another advantage is, he has not to resort to the common but clumsy method of discovering an erring plug by opening the coil box and holding down the trembler, so that one cylinder is left in at a time. These plugs appear to be dropping out of favor.

33. The Switch is a simple contrivance by means of which the primary circuit can easily be made or broken by a small movement of the metal connecting piece. The switch is used for momentary breaks in running the engine; by its use the current from the accumulator is *switched* on or off the induction coil. Of course the switch is used to break or make the circuit when the engine is stopped or started. There are several types of switch, the latest and most convenient for motor cycles being that operated by the preliminary movement of applying the brake.

34. An Interrupter is merely a means of conveniently breaking the circuit when the motor is not to be used for a considerable period. Motor bicycles are generally fitted with a plug interrupter, which can be carried in the cyclist's pocket when the machine is not being used.

35. The Complete Ignition System.—We may now summarize the various parts which, connected together, form the complete system. Commencing with the accumulator, Fig. 1, we have one of its poles connected with one end of the primary coil of the *induction coil*, the other end being connected (through the switch) to the brush of the *contact-breaker*, so that the low-tension current can pass through the disc to the engine frame and from the frame to the accumulator again, through the connecting wire (called earth wire). When the switch is on and the motor revolving, the half-speed shaft turns until the metal segment N touches the brush or collector O; this completes the circuit, and the current passes through the primary coil, agitates the trem-

bler, and the high-tension current is induced to the secondary coil. This high-tension or secondary current passes directly to the insulated portion of the *spark plug* (as shown, Fig. 11), and being, as it were, imprisoned on all sides by insulated material through which it cannot escape, jumps across the space between the platinum points, in the path of least resistance, and in so doing produces at the right moment a stream of intensely hot sparks in the gap between the sparking plug points, igniting the explosive mixture surrounding it. The high-tension circuit being completed through the engine frame and earth wire to induction coil.

36. Accumulators, Charging, etc.—The accumulator used for our purpose¹ usually consists of two cells, each with a voltage of 2·2, and being *connected in series*,² as they always are for this ignition apparatus, the result is a working voltage of $2 \times 2\cdot2 = 4\cdot4$, but when the cells are fully charged, it may almost reach 5 volts. There are several methods of charging accumulators, but we need only mention the following three. *First—Charging from primary batteries.*—This is a method that is within the reach of every motorist who is not afraid of a little trouble. The first cost of a good four-cell primary battery does not amount to much, and the same remark applies to the cost of charging, if all the materials are used up before they are replaced. If the motorist has only a very limited knowledge of electricity, he would be wise to get an electrician to arrange everything for him at first and this advice also applies to the other two methods to be explained; indeed, many car-owners prefer to send their accumulators to the makers, or to an agent who undertakes the work, to be recharged, rather than be bothered or run any

¹ Accumulators are used for lighting, as well as for ignition and traction.

² In series, the positive or peroxide pole of one cell (usually painted red) is connected to the negative or spongy lead plate of the next cell.

risk of making mistakes; but they should make an effort to understand these things to protect themselves, and to be able to put things right in case of emergency. The *second* method is by **charging from electric mains**, using lamps solely as a resistance: this is by far the most popular, but unless several cells can be charged at the same time, it is the most extravagant. The *third* method, which is by far the best when practicable, is to charge from electric mains, using, as a resistance, lamps which would in any case be used for lighting purposes. It entails a small outlay for slightly altering the wiring of the room to be used, but should the car-owner have the electric light in his coach-house, it can be easily arranged for the purpose, and the accumulators can then be charged when the lights are used for ordinary purposes, the only noticeable effect of this being a slight decrease in the intensity of the light; the current then practically costs nothing. An additional advantage due to this way of charging is that accumulators can be kept nearly always fully charged. Indeed, they should be charged whenever possible, to keep them in order. Of course, it must be *direct* current electricity, as an alternating current would charge and discharge with each alternation. Now, to keep the cells in order, it is best not to withdraw more than about 25 per cent. of the total charge from them before recharging; but much more, say up to 70 or 75 per cent., can be discharged if the cells are recharged immediately. They should always be fully charged before being put out of action for any considerable time, as there is a constant tendency for an automatic discharge to occur. The normal *discharge rate* through a coil of good construction is about half an ampère, so that if the accumulator cells have a capacity, as many of them have, of 40 ampère-hours,¹ and the read-

¹The *quantity* of electricity flowing into or out of an accumulator is computed in *ampère-hours*, and the *rate* at which it passes a given point in the circuit is indicated in amperes.

ing of the ammeter¹ is half an ampère, and about 50 per cent. of the total charge be withdrawn, it can be used for about 40 hours; but suppose the commutator only makes contact for one-fourth of a revolution, the accumulator is only giving current for one-fourth of the time, then it can be run for 4×40 , or 160 working hours.

All accumulators are constructed to charge and discharge at a certain rate, and any attempt to force the rate of either charging or discharging inevitably results in the peroxide paste being forced out of the grids, and the latter being bent and buckled by the stress. This often occurs due to *shorting*, when the terminals are connected by a good conductor to ascertain what charge, if any, remains in the accumulator. Of course this should never be done without a resistance, such as the coil, in circuit, nor should the ampère-meter be connected direct across the terminals, as in either case it would allow the accumulator to discharge at many times its correct rate. On the other hand, a volt-meter² may be connected in this way to take the reading, as it has a high resistance, and takes but an infinitesimal current.

This brings us to the question of measuring the charge in the accumulator.

37. The Voltage of the Current.—Let us assume that we have before us an accumulator consisting of the usual two cells fully charged, each to a voltage of 2·2, giving a voltage of 4·4 when connected in series and tested with the volt-meter. We may also assume that on being tested with an ammeter³ (connected up to

¹The *ammeter*, or *ampère-meter*, is an instrument for indicating the rate of charge or discharge in ampères.

²An instrument for indicating the electro-motive-force, or the electrical pressure in a circuit, or at the terminals of a battery or dynamo.

³In testing *dry batteries* for capacity, an *ammeter* should be used, not a *voltmeter*, because the voltage indicated when the battery is nearly run out is almost the same as when new; the resistance of the battery and voltmeter together

the coil whilst working and included in series connection¹) its discharge rate is found to be half an ampère, and that the charge is 30 ampère-hours,² we should find that as the current is discharged there is a gradual fall in the voltage, until, when about half has been withdrawn, the voltage would be only about 4, and if the withdrawal of current be continued, the fall in voltage becomes far more rapid till it drops to 3·6, at which reading the accumulator is considered to be exhausted or discharged.

38. Spare Accumulators.—It is usual to carry a spare set of accumulators, and these are often connected up by a two-way switch, so that they can be put in circuit and the others disconnected at any moment. This arrangement takes up no more room than the four-cell primary battery it often replaces.

39. Testing on a Closed Circuit.—The expedient of using a small incandescent lamp of the same voltage as the accumulator is a good one. This is connected across the terminals for a moment or two, and if it lights up brightly and the light is sustained, then there is a charge in the accumulator, but if it becomes dim, then

to the passage of a current being relatively high, whether the battery be nearly exhausted or almost new. On the other hand, an *ammeter* offers small resistance, and, if used just long enough to obtain a reading, will indicate by the quantity of current passing through it the condition of the battery; for as the battery becomes exhausted its resistance increases, and its capacity for giving out current becomes reduced.

¹The internal resistance of the accumulator being very low, unless a resistance, such as a coil, be placed in the circuit, both the ammeter and the accumulator would be damaged, the latter being quickly run down, and the winding of the former seriously over-heated.

²The amount of electric energy given out by an accumulator is always less than the amount put in; and the former, compared with the latter, represents the *efficiency*, which varies from 70 to 80 per cent., according to the age of the accumulator and the rate of charging, being highest when new and slowly charged.

the accumulator is exhausted. This test should always be *made at the conclusion of a run*, as the accumulator is capable of recovering sufficiently while standing to give a fairly bright light for a few moments, even when almost exhausted. As this is a test of current and voltage, it is very reliable, for a reading with a volt-meter (*testing an open circuit*) will sometimes be almost normal, and a fall of voltage occur as soon as current is withdrawn.

GOVERNING AND CONTROLLING

40. One of the most difficult problems the designer of a gasoline engine has to deal with is the governing of its power and speed. He is called upon to arrange its mechanism in such a way that the engine *automatically* prevents the production of more power in itself than is actually needed for the propulsion of the car at any particular speed. To give practical effect to this condition, designers have exercised their ingenuity in a variety of ways, but they have a more difficult task to deal with in the gasoline engine than in either the steam engine or ordinary gas engine, as we shall see directly. It is easy to make arrangements to enable the driver to *control*¹ the engine; and as these arrangements have much in common with those employed in governing, we may proceed to explain that the amount of useful work done by a gasoline engine during a cycle can be varied in several ways, the following being the best known.

- (1) Advancing and retarding the ignition, the charge being constant.
- (2) Advancing and retarding ignition with fluctuating charge.
- (3) Varying the amount of charge by throttling, *the proportion of the mixture being constant.*

¹The function of governing differs from that of controlling; the engine is *governed automatically*, but *controlled by hand*.

(4) By throttling the exhaust.

In order to grasp the general principles that underlie the working of the first and second methods, the reader must make himself familiar with the effect of—

41. Advancing and Retarding Ignition.—The power of the engine can be varied between fairly wide limits by varying the time of ignition. If ignition is to occur at the beginning of a working stroke for running the engine at its full power, the brush of the commutator (Figs. 1 and 16) should commence to come into contact with the metallic connecting plate on the insulated disc slightly before the piston has completed its compression stroke; as although, theoretically, sparking should occur at the instant the circuit is completed, an appreciable interval intervenes between ignition and the completion of the circuit. This is partly due to the number of points through which the current passes, some of which may not be very perfect, and to the fact that there is always an interval of time between sparking and actual ignition, the time required to ignite the mixture depending upon the proportion of air to spirit vapor forming it, upon the amount of compression, and also upon the proportion of the exhaust gases mingling with the explosive mixture. The interval being shortest when the mixture is perfect and at maximum compression, and increasing as the mixture becomes throttled with a smaller quantity entering the cylinder, which in mixing with the normal quantity of exhaust gases in the clearance or combustion space, results in an impoverished mixture at a lower compression,¹ and a later ignition. This being the case, the expedient of causing sparking to occur a little earlier, that is, by

¹The more the mixture is throttled, the smaller is the volume which is compressed in the cylinder, and the lower the pressure due to compression. Thus, if the cylinder is fully charged at atmospheric pressure, the charge be compressed to one-fourth the initial volume, then at greatest compression, neglecting refinements, the resulting pressure would be 4 times atmospheric pressure, or, say $4 \times 15 = 60$;

advancing the spark, is one that would suggest itself; indeed, it is the one that is generally employed, although in most cases in a somewhat casual way. The object should be to so time the ignition that the greatest pressure due to it occurs at the commencement of the working stroke at all speeds. Therefore the usual practice is to *advance the spark as the speed of the engine increases*, and, conversely, to *retard it as the speed is reduced*. Great care must be taken to avoid pre-ignition¹ with its attendant damaging effects. If the sparking is so timed that *ignition occurs after* the piston has started on its working stroke, the *ignition* is said to be *retarded*, and the effect of this is to reduce the amount of work done in the cylinder during this stroke. Engineers are able to examine the variation of pressure in the cylinder, during the complete cycle, by using an instrument called an indicator. When using the ordinary form of this instrument, a pencil point traces out a curved figure on a sheet of paper or card,² as it is called, and from it the pressure on the piston at all points in its stroke can be measured, a mean of these pressures giving the mean pressure³ throughout the stroke. The area of the figure formed by the expansion and compression lines (3 and 2, Fig. 12⁴) is a measure of the work done during the stroke, whilst the area of the figure bounded by the exhaust and suction lines 4 and 1 (same Fig.), represents the

but if, on the other hand, due to throttling the cylinder is charged with only half a full volume when the compression begins (this means doing negative work during suction stroke), then, obviously, the compression cannot exceed $2 \times 15 = 30$ pounds per square inch.

¹ Refer to Article 43.

² The ordinary instrument does not give satisfactory results at very high speeds, but the beautiful Hospitalier-Carpentier Manograph indicates efficiently at 2000 to 3000 revolutions.

³ This is the pressure which is used in measuring the *indicated horse-power* of the engine.

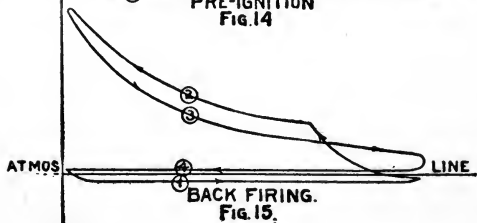
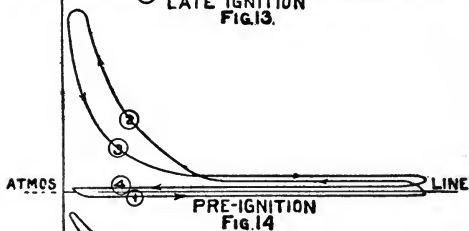
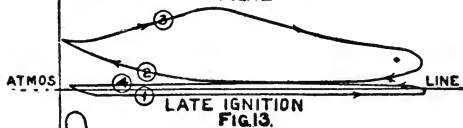
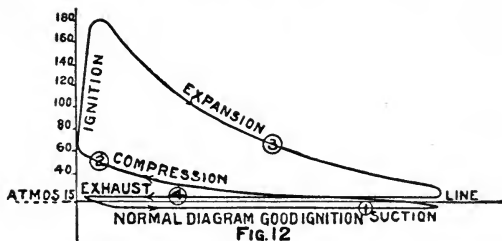
⁴ The Figs. are slightly contorted, so that all the lines may be clearly seen,

negative work done by the engine when acting as a pump during the suction stroke. The indicator diagram not only shows the behavior of the working fluid in the cylinder, but it reveals any defect in the valve setting, timing of ignition, and general action.

42. Late Ignition.—The diagram (Fig. 13) shows what occurs when the spark is retarded to reduce the power of the engine. It will be seen that the piston has traveled to nearly half stroke before the highest pressure (which is much less than in the normal case) is reached, the smaller area of the part 2, 3, showing the reduced amount of work done, although the same amount of mixture may have been drawn into the cylinder as for Fig. 12; but the rate of propagation of the flame throughout the charge is slow compared with the piston velocity, due to the lower compression, and the gases are only partially burned when allowed to escape by the exhaust, their temperature and pressure being much higher than in the normal case; indeed, the temperature is often so high that the long-continued action of the hot gases on the exhaust valves ultimately destroys them. Moreover, this is obviously a very uneconomical way of working, as about the same quantity of fuel is used per stroke for different powers, so all this shows the evil of governing by spark variation.

43. Pre-Ignition.—Fig. 14 shows how, when the mixture is sparked *too early* (pre-ignited), the explosion suddenly sends the pressure up to a high point, before the completion of the compression stroke, tending to stop the engine, and severely straining it. This action also leads to a certain amount of negative work being done in the cylinder during the cycle, as it will be seen that more work is done *by* the piston on the gases during compression, than is done *on* the piston during the expansion stroke. This *negative work* is represented by the area 2, 3.

44. Back-Firing, or explosion during the suction stroke or *early part of compression stroke* (Fig. 15),



sometimes occurs. It is caused by overheated valves or smoldering exhaust gases, and its effect upon the piston, etc., is similar to that just explained in connection with pre-ignition.

It will now be convenient to consider how the timing of the spark is actually effected, and an examination of Fig. 16 will help us in this matter, it represents a—

45. **Commutator or Current Distributor** of the Panhard type. T (Fig. 16) is the end view of the half-speed shaft, and M that of the disc, made of a non-conducting material, usually of a fibrous character; it is keyed to shaft T, and is fitted with a metal plate K, which is put in metallic contact with the shaft T, which is in the electric circuit, by means of a screw or pin N. The shell or body G has a boss at the back which is bored to fit the shaft, so that its arm or lever C can move it and its fittings freely in either of the directions shown by the arrows; into the projecting bosses HH insulating sleeves or brush holders FF are screwed, and into these again the brass tubes VV are screwed. These tubes contain the *brushes* BB, which are made of coiled wire gauze, held in contact with the edges of the disc by the helical springs SS, which press against the brass split caps DD; bolts or screws OO clipping the cap on the tube, the wires EE placing the brushes BB in metallic contact with the coils. Obviously, this commutator is arranged to serve *two cylinders* with cranks side-by-side, as in the Mors engine, the number of bosses HH and their fittings corresponding with the number of the engine's cylinders (with cranks at 180° , the bosses would of course be at 90° to one another). The link J is connected to the working handle by suitable rods, wire cables, and levers. A movement of C to the left, as can be seen, will cause ignition to occur later, or the spark will be *retarded*, just as a movement in the opposite direction will bring the brushes nearer the advancing metallic contact piece, and hasten ignition or *advance* the spark.

46. **Governing and Controlling by Throttling the Mixture**, sometimes called *charge volume throttling* (or *governing on the inlet*), is the system which is by far the most popular. A governor of the crank-shaft centrifugal type is fitted, usually on the half-speed shaft,

COMMUTATOR, OR CURRENT DISTRIBUTOR (Panhard Type) FOR CRANKS SIDE BY SIDE

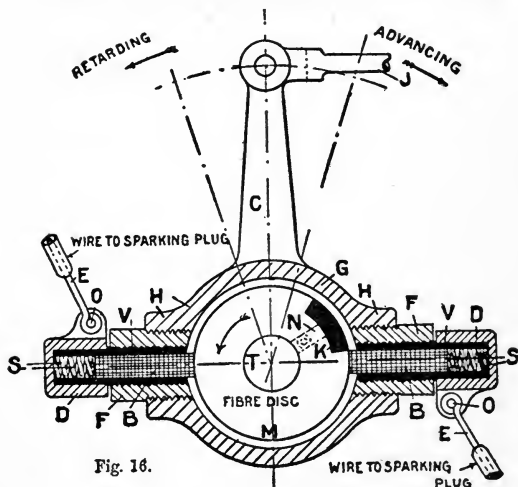


Fig. 16.

and arranged, in the majority of cars now in use, to actuate a throttle valve placed in the induction pipe of the cylinders,¹—this valve is either of the butterfly²

¹The quantity is regulated in the Duryea and Bollee cars by giving the inlet valve a variable lift.

²The tendency of many engines fitted with this valve is

(as shown in Fig. 6 at T) or cylindrical type. It is regulated so that when the car is running on level ground with a smooth surface, the engine is working in an economical manner; the governor only allowing sufficient explosive mixture to enter the cylinder to produce the amount of work that the resistance due to the condition of the road, direction, and velocity of the wind call for. Should this resistance increase, through any of the causes mentioned, or owing to the car coming to rising ground, the engine slows down and the governor automatically opens the throttle to enable a larger charge to pass into the cylinder, and, conversely, the governor commences to close the valve as soon as the engine begins to race above its normal speed. Some engines are so fitted that the throttle can also be controlled by hand or foot.

47. **Accelerator.**—To enable the engine to exert its maximum power for hill-climbing, an arrangement called an *accelerator* is fitted; it is merely a combination of levers, wire cable, and spring, fixed up to connect the governor to either a lever fitted to the steering column, or to a pedal projecting through the foot-board (the latter being the more usual arrangement), so that by a movement of the lever or pedal, the weights of the governor are prevented from exerting their power to close the throttle; in other words, it cuts out the governor's action, the throttle remaining open, allowing the speed of the engine to increase above its normal rate, and the engine to work at its maximum power, which is obviously what is required if a steep grade is

to run in jerks, first gaining speed, then slowing down too much under the action of the governor, or, in other words, the governor *hunts*; but this un-uniform action has been largely checked, and the running much improved, by drilling a hole about $\frac{1}{4}$ inch in diameter through the disc of the valve, to form a by-pass. Probably in some cases the uniformity of running would be much improved by the governor being fitted with a dash-pot arrangement, but at the best, with light loads, throttle governing is more or less unstable.

to be mounted without changing gear; but should the car then fail to make headway, the gear is changed to a lower one,¹ and the accelerator is thrown out of action, allowing the governor to act again, and the engine to run at its normal speed. The accelerator should never be used unless really required if the engine is to be economically worked.

48. Governing on the Exhaust.—In this system a hit and miss arrangement, actuated by a centrifugal governor of the crank-shaft type, permits the exhaust valve to be raised in the ordinary way when the engine is working within its maximum speed limit, but when the latter is reached a digger is withdrawn from the exhaust valve spindle or plunger by the action of the governor, so that the valve remains unlifted, and the burnt charge is retained within the cylinder; or the opening of this valve is retarded, a portion of the burnt gases remaining in the cylinder to dilute the next charge admitted. This so reduces the speed of the engine, that the next exhaust stroke is a normal one, and the ordinary cycle of operations is taken up again. With this system there is, of course, a loss due to back pressure, but the cylinder being kept full, the compression does not suffer, and the mixture is therefore more economically consumed, although, when the engine runs light, there is a loss of economy, as the incoming cold charge mingles with the hot burnt gases, making a high temperature mixture before compression. Not a little of the economy of the Gillet-Foust, and other motors, is claimed for this system of governing, and it is thought much of by some whose opinions are entitled to respect, although it has practically died out, and is only now seen on old cars which are still running.

¹ Drivers easily get into a way of manipulating the clutch to enable them to mount the crest of rising ground without changing gear. As the engine slows down, the clutch is momentarily withdrawn to allow the engine to gain speed, and is let in again before the car has had time to be much reduced in speed. For obvious reasons this expedient must be worked with moderation.

CYLINDER COOLING

49. When it is remembered that somewhere in the cylinder during each working stroke there may be a temperature of some 3600° F., tapering off to about 1800° to 2000° F. as the burnt gases pass out of the cylinder, and that the temperature of the cylinder-wall must be low enough to allow of the piston being efficiently lubricated, the importance of providing suitable arrangements for keeping the cylinder sufficiently cool can be realized. To make the conditions under which the piston can satisfactorily work in the cylinder a little more clear, it should be explained that the maximum temperature referred to is more or less evolved at the kernel of the mixture, the temperature near the cylinder-wall probably being not much more than half that amount, and that of the wall itself about 250° F. Further, these high temperatures are much reduced during the suction stroke, when the cool mixture enters, also during the compression stroke, although not to the same extent,¹ so that the heat imparted to the cylinder each cycle is not so much as might at first be expected; nevertheless, as an engine making 1000 revolutions a minute will perform a cycle in $\frac{1}{500}$ of a minute, or rather less than $\frac{1}{3}$ of a second, the rapid succession of heat increments could soon raise the temperature of the cylinder to a point when effective lubrication would be impossible, so to keep the temperature of the cylinder down to a safe point, special arrangements have to be made. So far as very small engines (such as are used on low-power motor bicycles) are concerned, it is sufficient to increase the outer surface of the cylinder, by an arrangement of either radiating or circular flanges or ribs,² so that in passing through the air it may be cooled as much as possible. The cooling efficiency of

¹ A great deal of heat is generated in compressing the mixture.

² Circular flanges are best, as the air can more completely sweep round them, and they materially add to the strength of the cylinder.

this arrangement (or of the air-cooled tubes of a radiator) depends upon the velocity of the encountering air, the extent of the surface in contact with that air, and the difference in temperature between the inner surface and the air in contact with the exterior surface. It is found that when this simple method is intelligently carried out, the cylinders of engines up to about 3 horsepower can be effectively cooled, but with larger powers the problem becomes one that requires the assistance of an additional cooling agency to solve it; hence the evolution of the arrangement diagrammatically shown in Fig. 1, where it will be seen that the cylinder has a jacket surrounding it, through which water is circulated¹ by a centrifugal pump² (P.C.) which forces the water to circulate through the cooling system, entering the jacket at the lowest part *a*, and leaving it at the top *b*, passing through the connecting pipe³ into the *radiator* to the tank⁴ at a level of about its center *c*, and leaving it at its bottom *d* to enter the pump again.

¹There is another system in use, in which cooling is effected by water *evaporation* within the jacket.

²This pump is found, on the whole, to be the most satisfactory for the purpose. If made a decent size, not requiring to be run at a high speed, and gear driven, as many now are, it works well, and is not affected by dirt in the water. Other types, such as the *rotary-force* and the simple *gear*, have been tried and used by a few makers, but although they give an excellent circulation when perfect, they soon wear out, and their first cost is greater, to say nothing of the difficulty of keeping their wearing parts lubricated without introducing into the cylinder jacket and tubes an oily viscous coating that much impairs their efficiency.

³These pipes are often made too small, and with bends much too sharp, to allow of a free and unrestricted circulation. They should not be less than $\frac{3}{4}$ inch diameter, and the bends should have a radius of at least some five diameters when practicable.

⁴The connections *c* and *d* to the tank should be as far away from one another as possible; so as to get a good circulation of water in the tank, they are usually placed at opposite ends, as shown. The tank is fitted with a filling hole, usually covered with a screwed bung, and an open tube from the highest part, bent over the tank side to allow any steam that may be generated to escape.

If the tank and radiator be sufficiently large, and fixed high enough above the engine,¹ a very fair *natural circulation* results without using a pump; in fact, this gravity or *thermo-syphon* system has the great advantage of simplicity to recommend it, and formerly was much used, and still is used with advantage on very light cars. Thus the introduction of *forced circulation*, with the indispensable pump, which in some form or another is general, has reduced the weight of the cooling system, and increased its efficiency, but has added to the number of parts which require attention and are liable to give trouble. The cooling system being a vital part of the motor, it greatly reduces the possibility of annoying stoppages when fitted so that in case of emergency the pump can be thrown out of circuit, and the engine run on low speed and power with natural or gravity circulation.

50. **Radiators.**—There are two types of *radiators* in use, namely, the *multitubular* and *coil*. The former was first brought out on the famous Mercedes car. In this the water is made to circulate around a great number (in some cases amounting to 5000 or 6000) of small tubes fixed about $\frac{1}{16}$ of an inch apart, its principal advantage being the small volume and weight of water used, some few pints only being required. Its drawbacks are that the workmanship must be of the very highest class, or leakage troubles will occur. Radiators of this type are very difficult to repair, and the passages being so very small, they are liable to get choked. In the other or ordinary type, the well-known ribbed or gilled pipe coil, the section of the pipe is usually circular,² and the surface of the gills flat, although

¹ Vibration, and the slight yielding of the frame when the car is roughly used, cause the connections to become leaky; so, for this reason, armored rubber hose is to be preferred for the connections, which should always be long enough to prevent undue straining actions.

² A flattened tube has a larger cooling surface than a circular one of the same sectional area, but it offers more resistance to the flow through it, particularly at the bends.

some of the latter are corrugated, the idea being that as they expose more surface to the action of the air, they are more efficient, but it has been proved that this is not the case, the corrugations retarding the passage of air between them, and causing as much loss of cooling effect as was gained by the extra surface. With either type a *float-glass*, in which the position of the float indicates the condition of the circulation, is fixed to the dash-board, or the water passes through a glass tube fixed there, so that the condition of the circulation can be seen at a glance.

51. **Air Fans** are now generally used, but unless these be skillfully designed, and run at a speed sufficiently high (which, by the way, requires a fair amount of power), they can easily *be worse than useless*.¹ Indeed, in not a few cases that the writer has come across, the efficiency of the motor would have been increased by scrapping the fan and paying a little more attention to the condition of the surface of the radiator, which should be so treated that heat leaves it with the greatest freedom. Now, strangely enough, all bright and polished surfaces reluctantly part with their heat,² whilst most dull rough ones freely lose it, therefore the common practice of blackleading and polishing cylinders and cooling pipes, or coating them with metallic paints, impairs the efficiency of the rough surface. The best stuff known for coating purposes is *lampblack*, and the rougher the surface to which this is applied, the more easily will it part with its heat.

52. **Air-Locking**.—Trouble sometimes occurs due to the system becoming *air-locked* in filling up with water, an air-bubble forming in the top of a bend and getting compressed and set instead of circulating when the pump begins to work. This of course means that the flow of water is stopped, with consequent boiling away

¹ They also draw the dust from the roads, and the hot air off the radiators on to the engine, which is a drawback.

² Part of the heat is carried or *conducted* away by the air in contact with the surfaces, and part by *radiation*.

of that portion of the water which is kept in contact with the cylinder, it not being free to pass through the radiator, which quickly becomes hotter at the upper part than at the bottom; so, if a sensible difference of temperature be detected in these parts after the engine has been running a few minutes, it means that there is either an air-lock or the pump is not working; if the former, it may sometimes be relieved by opening the air-cock, which is generally fitted to the top of the radiator, or, this failing to give relief, by drawing off the water and continuing to fill up the tank while the engine is running slowly.

MUFFLERS

53. No one can fail to have noticed what a marked improvement has been made during the past year or two in muffling, or *deadening*, the sound of the exhaust gases from gasolene motors, and all must agree that this

TYPICAL MUFFLER

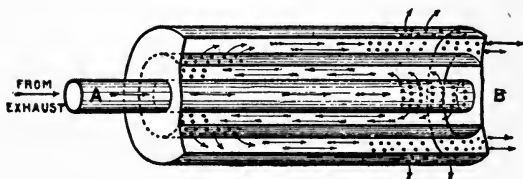


Fig. 17.

is a step in the right direction, indeed, one well worth making if we have not to pay too dearly for it in greatly reduced effective power, which is the price represented by want of skill in designing the silencer. The problem to be solved is, how to deaden the noise caused by the sudden liberation of the exhaust gases under pressure. The engine, as used at the present time, emits the

products of combustion at such a pressure that they expand violently, striking the surrounding air, and causing the sensation which we know as a noise or explosion. Now, the silencing method usually adopted is to muffle this noise by passing the gases into a cylinder of considerable capacity, to allow them to expand with little resistance till their pressure is equal to that of the atmosphere; their path through the cylinder being made more or less tortuous by baffles and perforated pipes, with the object of breaking up the sound-waves and reducing their velocity, so that the gases pass out of the silencer nearly inert and noiseless.

Another principle has been applied lately with a fair amount of success; the gases are discharged through a large number of little holes in a muffler of very small dimensions, the idea being to break up the large explosion into very many small ones, which, not synchronizing, more or less cancel one another. But any attempt to reduce the dimensions of the muffler below a certain capacity, which depends upon size of the cylinder and pressure of the gases as they leave the exhaust valve, must mean an increase of back pressure. Some cars are fitted with a *by-pass valve*, so that the driver can temporarily allow the gases to escape without all passing through the muffler, thereby reducing the back pressure, and giving the motor a little extra power when required.

A very good idea of how a typical muffler works can be formed by examining Fig. 17, where, if the arrows be followed, it will be seen that the gases pass through in a zig-zag way, increasing in volume, and, therefore, decreasing in pressure, as they near the outlet to the atmosphere at the end B.

54. **Back-Firing or Popping** in the muffler is nearly always caused through the mixture being too weak; the charge is not then exploded in the cylinder, but passes out of the exhaust valve into the muffler, where it is ignited by the heat of the exhaust pipe or passages. When the speed of a motor is suddenly checked, the

piston does not move quick enough to suck in a sufficient quantity of spray to carburate the air, so the remedy is to push the mixture lever forward when suddenly reducing speed.

TRANSMISSION GEAR

55. If a side view of the engine in Fig. 1 had been shown, it would have been seen that the crank-shaft is fitted with a fly-wheel, whose function in a reciprocating engine is well understood, as most people are aware that not a little of the even running of a gasolene engine, with its one working stroke in four, is due to this important part being of sufficient size and weight. Of course it is keyed to the tail of the crank-shaft, as shown in Fig. 18 at D, and in most cases it is made with a conical hole arranged to form, with the male conical block C, a friction clutch. This clutch is used to connect the road wheels with the motor through a mechanism called *the transmission gear*. And two forms of this gear now hold the field, one, called *chain gear*, in which side chains are used to drive the back road wheels, which are loose on the axle, and the other in which the power is transmitted to the back axle, by tooth gearing, causing it to rotate and carry with it the rear road wheels, which are in this case fixed to it. To understand these arrangements, and to be clear about what happens when a car is reversed, or put on a different speed by a change of gear, the reader is referred to Figs. 18 and 19, which diagrammatically show typical examples of these gears. The former illustrates the system of *Driving through Side-Chains*, and it will be seen that the male part C of the clutch is kept in frictional contact with the fly-wheel part D, by the action of the compressed helical spring S, the friction between them due to the spring being great enough to enable the engine to drive the car through the clutch. A bell-crank lever, with a fork at one end and a pedal at the other, is

fitted to the grooved collar M, as shown in Fig. 20, in such a way that when the pedal G is pushed, the spring is compressed and the clutch thrown out of action. Now, although this small end movement of the clutch cone C in relation to the shaft N can take place, they are so coupled¹ that when C is "let in," and is rotating about the axis, the shaft N is made to turn with it. Keyed to N (Fig. 18) are three wheels, E, B, and P (E and B are used for running ahead,² and P for reversing), each of which is arranged to mesh with one of the wheels on the sleeve GO. Now this sleeve is usually made with a square hole fitting the shaft RV, which is square to fit it.³ The sleeve has on it a grooved collar, which engages a sliding fork F, suitably connected at L, to the change-speed lever fixed at the right hand side of the car, and this lever works in a quadrant with four notches, one of these corresponding to the position of the sleeve shown with the *second speed*⁴ wheels in mesh.

Another position (due to a movement of L towards the right, and the lever into another notch) places the *first speed* wheels G and E in mesh, whilst a movement of L to the left throws all the wheels out of mesh, and the engine is free to rotate without driving the shaft VR. This of course is the position of the sleeve when the car is standing still and the engine is running, the change-speed lever being in the *neutral* notch. The fourth notch fixes the position of the lever for reversing the car. When this notch is used, the sleeve is moved

¹The clutch C driving the shaft N through a feather fitted to the latter.

²It will be noticed that, for simplicity's sake, the *gear-box* in this example only contains two pairs of forward wheels and a reverse, corresponding to two speeds of the car for a given speed of the engine. Of course, a motor arranged in this way would be more dependent upon the elasticity of the engine (or power of varying its speed) than one fitted with three or four speeds.

³Or the shaft is round, and fitted with a feather arranged to drive the sleeve.

⁴In this case the highest speed.

TRANSMISSION GEAR.—DRIVE THROUGH CHAINS.

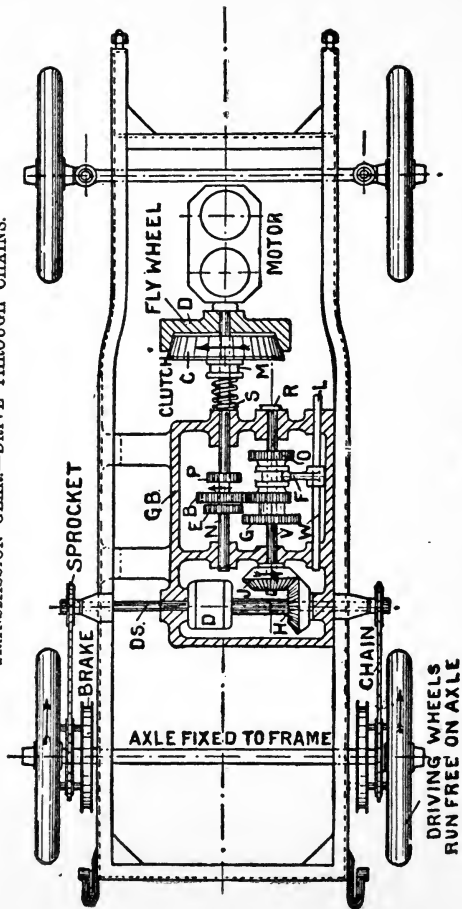


Fig. 18.

to the left till the wheels O and P are opposite. O then comes into mesh with another wheel, called a change wheel, running on a third shaft above it (not shown in the Fig.) which connects the two wheels, but causes the wheel O and the shaft VR to rotate in same direction, thus reversing the car.

It should hardly be necessary to explain that the shaft VR drives the differential shaft DS, through the bevel wheels J and H and the box D containing the differential gear¹; the shaft DS, in its turn, driving the road wheels through the chains as shown, and in the way that everyone who owns a common bicycle understands.

The other kind of transmission gear referred to is the—

56. Live-Axle or Cardan Drive, in which the power of the engine is transmitted to the road wheels by *tooth-gear* throughout. This system, which is becoming increasingly popular, can be understood by an examination of the explanatory diagram Fig. 19. It will be noticed, that from the motor to the gearing box GB, the mechanism is the same as in Fig. 18; indeed, the greater part of the gear and box is identical with that previously described in connection with that figure, but in Fig. 19 the tail of the shaft GR is connected to the bevel pinion *c* by the propeller or Cardan shaft *ps*, two flexible or universal joints² *a* and *b* being fitted to the shaft to allow full play of the carriage-spring system between the road-wheel axle and the frame which supports the motor and gear-box.

Now the bevel pinion *c* is in mesh with the bevel wheel *d*, which forms part of the differential gear-box T, through which motion is transmitted to the axle of the driving wheels.

¹One form of this interesting and indispensable gear is shown in section on the live-axle in Fig. 19, and its action is referred to in the next article.

²These joints are perhaps best known as Hooke's, the inventor being Dr. Hooke, the famous scientist. They are also sometimes called Cardan joints.

TRANSMISSION GEAR.—LIVE-AXLE OR CARDAN DRIVE.

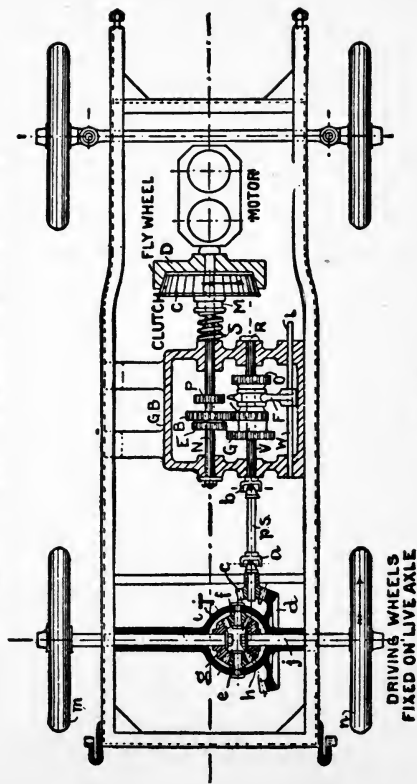


Fig. 19.

It will now be convenient to give a little attention to some of the details that have been referred to in connection with the two systems of transmission, so we may commence with—

57. The Differential Gear, which is a train of wheels elegantly arranged to *average* the speeds of the two driving wheels, for, when the car turns a corner or runs round a bend in the road, the outer road wheel will be traveling faster than the inner one; but the propeller shaft can only revolve at one speed at any given moment, and that, therefore, must be the average of the two speeds, due to the running of the inner and outer road wheel. Although it is not easy, without suitable drawings, to make clear to the general reader how this arrangement works, the following experiment will help him, at any rate, to understand the function of this important fitting. Jack up the road-driving wheels to clear the ground, place the change-speed lever in the neutral notch, then turn by hand one of the road wheels n (Fig. 19), and the other wheel m will revolve in the opposite direction at the same speed, the average speed being zero. Again, let one of the wheels, say n , be fixed, and the bevel wheel d be turned, it will be found that the other road wheel m will revolve at twice the speed of d ¹ or the speed of d is the average of the speeds of m and n , as before. And so, if in turning a corner n revolved at 70 a minute and m at 80, d would be running at the mean or average 75.

One of the most important details of a transmission gear is—

58. The Clutch, as at any moment, when a car is running, the safety of the vehicle, indeed, the safety of the

¹ The box T revolving with the bevel wheel d carries with it the two (or more) bevel pinions (called epicyclic, owing to their movement around the axis of motion) e and f , which, being in mesh with the stationary pinion h , cause the pinion g , and the axle i to which it is fixed (h being also fixed to axle j), to revolve at twice the speed of d , the pinion g being carried round once by e and f and driven once by being in mesh with h .

occupants, may be jeopardized by its faulty action, for, when in working order, a push on the pedal instantly disconnects the motor from the transmission gear, and the car can be stopped by an application of the brakes; but should the clutch seize at a critical moment, this release cannot be made without a deal of trouble, and it is easy to imagine what might happen. Fortunately, this is a mishap which rarely occurs, indeed, should never occur, if the clutch is made with a suitable taper, and care is taken in a metal to metal contact to keep the surfaces lubricated. In this connection it should be explained that the surfaces of the male cone is generally faced with leather,¹ to increase the amount of friction, copper being occasionally used instead.²

59. Fierce Clutches.—Clutches may cause trouble, either by slipping too much³ or by not slipping enough; in the latter case they are said to be *fierce*, and the cause

¹ The leather is usually riveted to the conical surface of the male part of the clutch by copper rivets. These are first screwed into the cone and hammered down, till the heads are rather more than $\frac{1}{8}$ inch below the surface of the leather, the holes in the latter having been previously countersunk. When the riveting is completed, a light cut is taken off the leather in a lathe, so that its surface is truly conical and the right taper. The leather ultimately wears down to the rivets, and when this occurs, the clutch is apt to become very fierce, owing to the rivet heads seizing the metal of the clutch; they then require hammering down till they are well below the surface again.

² There appears to be a growing tendency to dispense with a facing, and run the clutch with bare iron contact.

³ Slip may be due to too much oil getting on to the leather face; this may be remedied by applying a little Fuller's earth, chalk, or lime. But slip may also be due to the spring being too weak; if this be the cause, the spring must be further compressed by screwing up the adjusting nut. The clutch should be so adjusted that it is just on the point of slipping when the car is exerting its full power in mounting a hill on its lowest speed. Often this means a good deal of strain on the ankle for a long run, and the temptation to ease the spring is great, but it should be remembered that slip means loss of power.

is either the presence of gritty dirt on the leather,¹ or the spring being too strong. If due to dirt, the leather should be washed with gasolene, and dressed with a small quantity of castor or Collan oil; this makes and keeps the leather soft and pliable, and allows the necessary slip to take place should the clutch be accidentally allowed to too suddenly engage. If this treatment does not improve matters, and the clutch takes up its work too rapidly, causing the car to plunge forward, subjecting the whole vehicle to abnormal strains, instead of gradually moving off, as it should do, then the compression of the spring must be relieved by unscrewing the adjusting nut to increase its length. A little patient attention to these matters will enable the driver, by a give and take correction, to put the clutch in proper working order. Of course, with a conical clutch as ordinarily arranged, there is a certain amount of thrust in both directions, due to the spring, which requires attention, this being sometimes taken on ball bearings; and it is owing to this that expanding clutches, which cause little or no thrust, are coming into use, but the difficulty has been ingeniously overcome in—

60. The Panhard Clutch, which is diagrammatically shown in Fig. 20. It will be seen that in this arrangement the dished fly-wheel F is bolted on to the tail of the crank-shaft CS, which is flanged at A for that purpose. Through the rim of the fly-wheel, pins PP are fastened, the projecting parts passing through holes in the flange of the male cone C to enable the fly-wheel to drive the latter. The female cone B is attached to the hollow clutch shaft N,² so that when the clutch is engaged, the helical spring S presses the grooved collar M against the cone C, forcing it into cone B, and in so

¹ Fierceness is also caused by renewing the leather facing; the remedy is, apply the clutch gently until the leather wears down and becomes fairly smooth.

² This shaft is usually coupled to the change-gear shaft N (Fig. 18) by a sleeve, inside of which is a distance piece, so that by opening the coupling sleeve and removing the distance piece, the clutch and shaft can be removed.

doing creating friction enough to enable the car to be driven through the clutch. The reaction at the other end of the spring is exerted by the adjustable collar-nut D, so that the opposite forces are completely balanced, without any thrust being thrown on the crank-shaft or gear-box. This balance, it should be explained, is dis-

PANHARD CLUTCH.

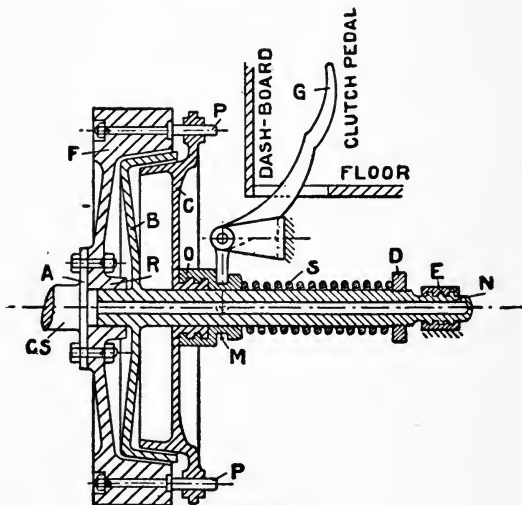


Fig. 20.

turbed when the pedal G is pushed to disengage the clutch, an additional pressure is then exerted on the collar D, thrusting the shaft N to the right, but a thrust block E is arranged to receive that. There is also a thrust bearing at O to transmit the thrust of the spring to the cone C. It will be noticed that the

cone end of the shaft fits into the boss R of the fly-wheel, thereby keeping the shafts in perfect alignment, which is a most important condition to satisfy. In some cars, such as the Canstatt Daimler, and the Mercedes Simplex, the withdrawal of the clutch automatically reduces the speed of the engine, whilst in most cases the act of applying the foot-brake disengages the clutch.

61. Gear Changing.—In the case of cars fitted with the ordinary or Panhard gear, one of the most delicate operations the driver has frequently to perform is *gear changing*, for if this is not done with sufficient skill and care, the teeth of the wheels are apt to be seriously damaged and the car abnormally strained. We have seen that in changing from one gear to another, the teeth of the wheels which are in mesh have to be disengaged and those of others put into mesh by a sliding movement; now, obviously, for this to be done sweetly, the spaces must be just opposite the teeth they are to engage, but should they not thus coincide, much grinding, if not a broken tooth, may result in a clumsy attempt to engage them.¹

Certain precautions should be taken in gear changing; for example, let us suppose that a car is in motion on fairly level ground, with, say, the second speed gear in, and it is decided to change up to the third speed, the clutch pedal should be pressed down to disengage the clutch and allow the car and gear to continue running by its momentum, then with a pull on the speed-lever the second speed wheels are disengaged, and an

¹This gear is without question the weak link in the ordinary car; that it is a barbarous device, although a convenient one, no one doubts, and its ultimate disuse as at present arranged can be sagely predicted; although they have been much improved by beveling the tooth-faces and increasing the pitch, it is not so easy to indicate upon what lines further improvement will be made. There are already in use gears that can be easily and safely changed, the teeth being always in mesh, the tightening of a band-brake bringing a particular gear into use.

attempt made to put into mesh the teeth of the third speed wheels; this must not be done until the delicate sense of touch has conveyed a message that spaces and teeth coincide, when a sharp pull or jerk will engage the wheels. Now, in running on the level or on a down grade, this operation need not be performed hurriedly, indeed, it is best done gently; but in putting in a lower gear up-hill, not a moment is to be lost, otherwise the car rapidly slows, and if time is lost in the change, the load on the engine suddenly becomes greater when the wheels get into mesh, often requiring a little relief by slightly disengaging the clutch, allowing a little slipping to keep the engine running above the speed at which it is apt to stop. There is always the danger, when changing speed in mounting a hill, of missing the gear altogether, the car then quickly commencing to run back. In fact, not a few most serious accidents have happened in this way. This being so, we will carefully indicate what should be done in negotiating a hill which requires a change of gear. Now, as soon as the car gets on rising ground, the accelerator pedal should be pressed to allow the engine to exert its full power on the gear it is running with (which will probably be its highest one), then, immediately before withdrawing the clutch, the accelerator pedal is released,¹ and on the clutch being disengaged the speed-lever is promptly moved over to the required notch,² corresponding to the second or first speed, as the case may be, and when this has been done the clutch should be gently put in, allowing slip to occur, until the engine takes up the full

¹This enables the governor to check the racing of the engine during the moment or two required for changing the gear.

²A deal of practice is required to do this with certainty in the dark or without looking. The expedient of connecting a little electric light-up with the gear-lever and the ordinary four-volt cells used for ignition, in such a manner that when changing gear the light automatically comes into action, and immediately goes out again on reaching the proper notch or gear, was introduced some year or two ago, but there are obvious objections to its use.

load, when the clutch pedal is released and the accelerator put in action. Briefly, a gear should be put in at the moment the two wheels that are to be placed in mesh are running at the same circumferential speed.

62. Chain Driving.—Although during the past year or two there have been an increasing number of makers who have adopted the system of live-axle and gear transmission, particularly for light cars, there are still a great many who pin their faith to chain driving, with its rather greater simplicity and flexibility, the fact of the matter being that either system is in a way a compromise, each one having its advantages and disadvantages. The former system, perhaps, on the whole, is considered by engineers the best mechanical arrangement; certainly the working parts are better protected, but the divided axle is a drawback, and should it accidentally get bent, it means a big job to get it right again, or even true enough to get home with, whilst a village blacksmith can straighten the axle of a chain-driven car with certainty. On the other hand, chains are apt to break, and should one give way and the other continue driving, the car may be overturned if going at a high speed; of course, most cars carry a spare chain, or at least spare links that can be fitted on the road should it be necessary. After chains have been in use some time they stretch and become loose, and have to be taken up either by lengthening the stretcher bar¹ or taking out a link. Chains as ordinarily used are rarely run at their highest efficiency,² as it is quite the exception to see any attempt made to properly lubricate them and keep the dirt off. Users of the common bicycle

¹The stretcher bar, or distance rod, is used as an adjustable connection between the axle and the differential shaft, the distance between which would vary considerably with the deflection of the springs were this rod not used.

²When the teeth of the sprocket wheels are correctly formed, it is mostly rolling friction which occurs, and this accounts for the liberties that can be taken with chains in lubricating them. But the want of alignment, that is so often noticed, even in the best cars, means loss of efficiency.

understand the advantage of using a gear-case with the chain running in oil; it is true that there are difficulties in fitting cars this way, but it is not easy to understand why some protection has not been more generally given to car chains; so, as things are, periodical attention must be given to—

63. Cleaning and Lubricating the Chains.—They should be first thoroughly cleaned with paraffin, then soaked in melted refined¹ Russian tallow, care being taken not to allow the tallow to become hotter than is necessary to keep it in the liquid state, as the temper of the chain may be affected. After the chain has been moved about in the melted grease to allow it, the grease, to come in contact with the surfaces of the rollers and rivets, the chain should be hung up and the lubricant allowed to drain into the shallow tin used for the purpose. Plumbago and tallow make an excellent lubricant, but it is very difficult to effectually apply, as the plumbago sinks to the bottom of the vessel as soon as the tallow becomes melted.

64. Brakes.—Every car must by law be fitted with at least *two* brakes, but most cars of any importance have three, one at each driving wheel, and one somewhere on the primary shaft, and it is almost the universal practice to make one of these (generally the latter) a foot-brake, arranged to withdraw the clutch as the brake is applied, and in some cases to also throttle the mixture. The second brake (or brakes) is usually worked by a side-hand lever; this brake should on no account be made to disengage the clutch when it is used, as the engine itself can be made to act in cases of emergency as an auxiliary brake,² if the clutch remains engaged.

¹The tallow can be refined by placing it in a pail of boiling water, stirring till it is all melted, when the foreign matter will be precipitated, and a solid block of clean tallow form on the surface when cooled.

²A car sometimes stops on a hill, which for some reason or other it can't climb; the tendency then is for the weight of the car to gradually make the engine run backwards and allow the vehicle to descend the hill; of course, as soon as

Most cars are fitted with band brakes on the driving wheels, as shown in Fig. 18, but several makers have abandoned these in favor of some form of expanding brake acting on the inner surface of a ring or annular flange.¹ It is imperatively necessary that all car brakes should be so constructed that they are equally effective whether the car be moving forward or backward, for upon the perfect working of the brakes depends the safety of the car and its occupants.

The conditions which a good brake should satisfy are the following:—

(1) The maximum force required to work it by foot or hand to be one that can be applied without undue exertion.

this happens the sprag should be lowered, and if this holds before the car gets on too much way all is well, but it is easy to see that so long as the clutch is in, the friction and compression in the cylinder retard the motion of the car, and the withdrawal of the clutch cuts out this resistance, often with a resulting increase in the velocity of the car before the hand or emergency brake can be put on, although the foot-brake be at once applied. This must not be confused with what is done when a car is running forward, and its speed is suddenly arrested by an application of the brake; the foot-brake is then used, the clutch being withdrawn by the same pedal, instantly disconnects the clutch shaft from the engine, which then runs unloaded. This arrangement gives the driver wonderful control over the car, as its stoppage is not dependent upon his power to suddenly bring up his engine to a standstill. Of course the beauty of the system is that when the car is temporarily stopped the engine continues running, so that a restart can be instantly made by letting in the clutch. Indeed, it is not easy for those who have not driven a car to understand what perfect control the driver has over it; for instance, it was proved by brake tests carried out by the Automobile Club of America that over 70 feet were required to pull up a four-in-hand coach running at about sixteen miles per hour, whilst a Panhard car running at the same speed was brought to a standstill in 25 ft. 4 ins.

¹In chain drives this is a particular form of sprocket ring. With such arrangements it is practicable to better protect the rubbing surfaces from oil and dirt, which reduce their efficiency, and increase the wear and tear, but they are less get-at-able and more difficult to examine.

(2) The movement of pedal or lever to apply the full power of the brake not to be more than can be conveniently made by the driver.

(3) The bands or blocks to be suspended in such a way that they are only in contact with the brake, pulley, ring, or flange when the brake is applied,¹ being at least a $\frac{1}{4}$ inch clear all round at other times.

(4) Absence of *fierceness* in the action of the brake.²

No part of the car requires more intelligent care in its manipulation than the brake, if it is to be worked when necessary for all it is worth without abnormal injury to the tires. It works with the greatest effect when the tires, due to its application, are just on the point of skidding;³ for when skidding occurs the rubber is eroded, and the friction between ground and tire is very much decreased instead of becoming greater, as most people would expect.

65. Ball Bearings.—Readers who are old enough to have ridden a bicycle before the introduction of ball bearings, and have had riding experience with both kinds, will be in a position to estimate the marked advantage ball bearings have over ordinary ones, so far as frictional resistance is concerned, and with cars this difference is just as striking; indeed, a few things appear to be more perfect than the running of car wheels, mounted on well-adjusted ball bearings; but the ball bearing has an advantage over the plain bearing, only so long as the hard steel balls remain in perfect form,

¹ A common source of trouble in the way of noise, wear, and loss of power, is the rubbing of brake-bands, due to want of adjustment or faulty construction.

² The true function of a brake is to retard a wheel, not lock it; should it do the latter, then the tires must skid, and the most expensive part of the car (the tires) is seriously worn and injured, instead of a little wear occurring in the strap and ring, which can be easily replaced.

³ The old-fashioned spoon-type brake, acting directly upon the tread of the tire, was abandoned on account of its low efficiency and the manner in which it used to wear out the cover of the tire.

and no longer, for should a ball break, there is always the probability that a portion or portions of the ball may get across or become jammed in the ball races, scoring them or the axle, or both, whilst in some cases the axles have been held tight and fractured by the sudden strain. Frequently ball bearings are allowed to run far too long without attention and lubrication, with the result that when they are inspected some of the balls are found to have worn sharp or rough, and perhaps to have grooved the cups and cones of the races upon which they run. Renewing the latter is, of course, an expensive matter; it is much more economical to replace the *whole* of the balls as soon as there is any appreciable sign of wear, even if a single ball is faulty, as a new one would have to be exactly the same size as the others, and few people are capable of gauging the size with sufficient accuracy. Obviously, if one of the balls happens to be a shade larger than the others, it will, each time it reaches the bottom of its race, support the whole weight, and sooner or later will break. To be on the safe side, these bearings should be examined every 1000 miles, and the balls renewed about every 5000 miles. In placing balls in their races, care must be taken not to get them too crowded; indeed, if there is any doubt as to whether a certain number can be got in, it is better to put in one less, and be sure that they are not jammed together when the cone is screwed up.

If no lubricator is provided for the hub barrel, the axle cap should be taken off, filled with grease, and screwed right home, every few hundred miles; this will force the grease into both races, and keep things right. Ball bearings require careful adjustment to keep them in order, the adjusting cone being tightened till all side shake has been taken up, and the wheel is solid on its bearing; at the same time, it must run with the most absolute freedom. Of course this adjustment can only be made when the wheel is jacked up clear of the ground; and it should be remembered that the adjust-

ing nuts, upon the right-hand side wheels, are made with a right-hand thread, whilst those on the left-hand side of the car are fitted with a left-hand threaded adjusting nut. The reason of this arrangement should be obvious, for should the lock-nut by any means work loose, the tendency of the adjusting nuts on both sides, due to the motion of the wheels in contact with them, is to tighten themselves upon the axle.

66. The Tires.—We may now give some attention to the vexed question of the tires. Should they be solid or pneumatic? is a question, like so many others relating to motor vehicles, that cannot be answered definitely without qualifications. The principal factors which have to be considered in making a decision, being the maximum speed the car is to run at, the character of the roads the car is to run on (*i.e.*, is the car required for town or touring purposes?), the weight of the vehicle, the size and flexibility of its springs, comfort, and reliability. Those who have had long experience with pneumatic tires, particularly if they have run them after they have given unmistakable signs of depreciation, would willingly sacrifice a little comfort if they could secure immunity from tire troubles by adopting solids; but even with solid rubber tires we have not perfect reliability, as, under exceptional circumstances, the fixing cement is apt to get heated enough by road friction to melt, and allow the tires to creep slightly on the rims, the cement accumulating at some parts of the latter to an extent sufficient to gradually force the tires from them, causing, at the same time, an abrasive action between the tires and rims, the tendency of the tires to leave the rims being increased by the centrifugal force, when running at a high speed. Moreover, the use of solid tires necessitates the use of springs of greater flexibility; and provision must be made for a greater vertical movement between the frame and axles, which means, in most chain-driven cars, a varying tightness of the chains, and in gear-driven ones, a greater variation in the uniformity of transmission, due to the

greater obliquity¹ of the propeller shaft. But, notwithstanding these drawbacks, there are many who pin their faith to solid tires, particularly for town use, as the roads are generally fairly good, and the speed rarely exceeds some sixteen miles per hour. An additional advantage may be mentioned, and that is, there is not quite so much skidding with solid tires as with pneumatic ones. So, for those who never wish to exceed a most moderate speed with the minimum of tire troubles, particularly if they are not too exacting where their ease in riding is concerned, solid tires, fitted to a light but strong car, *built for their use*, would be a wise selection. On the other hand, it is not easy for anyone who has once enjoyed the luxury of driving in a good car, suitably fitted with pneumatic tires, to revert to solid ones; indeed, the temptation to run the risk of trouble, and take his chance, seems almost irresistible; but we must be careful not to in any way exaggerate the disadvantages of pneumatic tires, for, in addition to their wonderful resilience, they run, when properly inflated, with less resistance than solids, and if they are, in the first instance, of suitable size² and of good quality (as they would be if supplied by any of the famous makers), and proper care is taken of them when in use,³ also when they are stored or on the wheels of a laid-up car,⁴ they may be expected to run some 3000

¹ When the universal joints of the propeller shaft come into use, they cause, or tend to cause, a difference in the uniformity of running of the clutch shaft and driving wheel axle; that is to say, if the former was running with uniformity, the latter would be moving with slight variations for each turn of the propeller shaft.

² There is a tendency on the part of many makers to keep down the size and weight of pneumatic tires to such an extent that, from the first, they are overloaded. If in doubt as to the size, it is always wiser to err on the right side, and use a tire of ample size and strength.

³ Refer to footnote on Brakes, page 78.

⁴ Rubber commences to deteriorate if exposed to a strong light or high temperatures, or if brought in contact with rust, grease, or most of the acids. So spare tires should be protected from the light, and stored in a place the temper-

or 4000 miles before they require replacing (solids, if of the best make, run over twice the distance and cost about half as much); of course, the first serious trouble may be due to the inner tubes commencing to perish; if so, these can be easily and comparatively inexpensively replaced. Every driver of a touring car should be able to repair a puncture, and to lace a leather sleeve gaiter or shoe over the outer cover of a tire and around the felloe of the wheel, should a cover burst on the road. Needless to say, tires which have suffered from bursts should be returned to their makers at the earliest opportunity, so that the cover may be properly repaired and vulcanized. It is a great mistake to run a car with soft tires, as many are tempted to do, either by the easy running, or to avoid the trouble of pumping up; it means excessive wear and rapid depreciation. They should be inflated until they are just on the point of bulging at the tread under the full load; this is a better guide than a pressure gauge, as gauges are not always to be relied upon, and after the covers have become worn a given pressure¹ has a different effect upon them. When cars are garaged or stabled for several weeks they should be jacked up, so that the wheels are clear of the ground, and the fabric liners of the tires are not continuously under stress; if this is done, it is not necessary to deflate the tires. An occasional wipe with a damp sponge will keep them in condition if they are not exposed to heat and sunlight, as previously ex-

ature of which does not exceed some 75°F. Although tires which have been in use are not so much affected by heat and light as new ones, care should be taken to protect them if the car is laid-up for any time, and to remember that they can only be kept in good condition by washing the mud and dirt off them after every run. In removing the cover from the rim of the wheel, the paint is sure to be more or less injured, and if such exposed parts are not painted again, when an opportunity occurs, with some air-drying enamel, rust will accumulate and injure the tire.

¹The pressure per square inch varies from about 35 in the tires of the lightest cars to about 110 in those of the heaviest.

plained. The covers, inner tubes, and rims require periodical examination for any of the defects that have been referred to. Abnormal wear on the front tires always occurs when the front wheels are not in alignment with the rear ones, that is to say, when their horizontal diameters are not parallel for the position they are in when the car is running forward in a straight line. Any want of such alignment means a combined rolling and sliding, or grinding action, as the wheel passes over the ground. A similar action occurs when, through some defect in the design of the steering gear, or through some straining action, the front wheels do not come to the proper angles which they should make with the front axle when turning a corner. These angles are only equal when the car is running in a straight line, but when turning a corner the near-side wheel should be running in a sharper curve than the off-side one for correct running, therefore the gear must guide it into a position, making a smaller angle with the axle than the off-side one does. A very simple and familiar expedient enables the designer to arrange his steering gear to do this; but it is often in the actual construction of the car that such adjustments are apt to be made without sufficient care, although, of course, in the works of the best makers both at home and abroad, so great is the care taken that such parts are little short of perfect when the car is turned out.

67. Road Wheels.—The designer cannot give too much attention to road wheels. These are made of either oak or metal, the former, known as the artillery wheels, being now almost exclusively used, as they wear very well, have a better appearance than the others, and are more easily cleaned. But it can be proved that motor-car wheels, to have a margin of safety equal to that which the wheels of horse-drawn vehicles have, must be many times stronger; in fact, they cannot be too strong for our purpose, as the very lives of motorists depend upon the wheels being able to safely withstand the tremendous strain set up by turning a corner

at high speed, or by any obstruction that tends to dish them at a time when they are transmitting considerable power. This is one of the reasons why motor-car wheels are kept down in size, although it is common knowledge that the larger the wheels, the less power required to drive a given carriage. There are other reasons why large wheels are not used, for they greatly increase the cost of both wheels and tires, and make access to the seats more difficult, whilst they raise the center of gravity of the vehicle, reducing its stability in turning corners. On the other hand they run smoother, lick up less dust, and more easily surmount any obstacle. So again we have a compromise.

68. Balanced Engines.—Perfect smoothness of running can only be secured by fitting the car with a well-balanced engine. This would appear to be a very easy matter, as almost every maker of a gasoline engine claims that it is perfectly balanced, whether it be a single-cylinder one, a two-cylinder, three-cylinder, or whatever number of cylinders it may have. In fact, when balancing is thus referred to, a very loose interpretation of the word is, or should be, intended. The balancing of a reciprocating engine might appear at first to represent the very simple problem which in the single-cylinder engine is usually solved by forming weights on the crank arms (as shown in Fig. 1) to balance the revolving and reciprocating masses; but after this has been done (without going into refinements that would be of interest to an engineering student, but could scarcely be followed by the general reader), there remain in the vertical engine *unbalanced inertia forces*, caused by the moving parts, which produce a vertical hammering action. Now, if instead of a single-cylinder engine we consider a *two-cylinder engine*, with cranks at 180° , and reciprocating masses equal, there are certain forces and couples which cannot be balanced, and they result in a tilting effect which tends to rock the engine in a fore and aft direction, and cause serious vibration. But with *three cylinders*, with equal masses

at the crank radius, and the cranks at 120° , the engine can be arranged to run with a more uniform turning action, and with the vertical hammering action practically eliminated, a distinct advantage over the two-cylinder one; but, so far as the rocking action (due to certain unbalanced couples¹) is concerned, this engine has little or no advantage over the two-cylinder one of the same power. Now, by adding another cylinder, we get a *four-cylinder engine*, which gives the designer a much better chance of approximating to a true balance, for with cranks at 180° apart, the usual arrangement in motor-car engines, a perfect fore and aft balance is possible; but the vertical hammering effect can only be imperfectly dealt with, in fact with no more success than in a two-cylinder engine. Notwithstanding this, it cannot be denied that four-cylinder engines are produced which, when run at the speed they were designed to work at, are hard to beat for smoothness of running. But those who have paid attention to these matters will know that to attain the highest possible condition of balance in an engine, five or six cylinders are necessary. Even with the required number of cylinders, the exercise of consummate skill in designing the balancing system is necessary to produce an engine that will run without vibration; indeed, a wealth of mechanical genius has been lavished on the evolution, of the highest form of gasoline engine, and some elegant expedients have been devised in solving the balancing problems.² So it will be seen that the balancing of engines is a subject on which the man in the street is not likely to be very well informed, in fact, is most likely to be easily misled.

69. Lubrication.—No car can be efficiently run without trouble occurring, or even a breakdown, unless it has been constructed in such a way that all the wearing

¹ To keep down the disturbing effect of these couples (the primary and secondary), the cylinders should be placed as near together as practicable.

² One of the most interesting of which is to be found in the Lanchester engine.

parts can be easily and properly lubricated. No driver can hope to run his car without trouble, unless he has made a business of mastering the arrangements made for lubricating its various working parts and understanding the maker's instructions relating to them; indeed, he should never take a car out without first being sure that everything connected with its lubrication is in order, for, obviously, it is too late to commence to pay attention to such matters when he hears ominous sounds emanating from bearings or rubbing surfaces, that plainly tell him that they are on the point of galling or seizing for want of proper lubrication. New engines in particular require plenty of the best oil, as they are more apt to give trouble until all their bearings have rubbed down to their work. Much ingenuity has been displayed in designing the innumerable forms of lubricators and lubricating devices in common use on cars for securing a regular feed to the various bearing surfaces, with the result that they not only vary with the car, but with different parts of the same car. The most perfect way to lubricate a bearing is to immerse it in an oil-bath, and the more nearly this ideal arrangement (which is rarely practicable) is approached, the more satisfactory the result; but a close approximation to this is to be found in the admirable forced or circulating-pump lubrication employed on the Maudslay, Mercedes, Wilson-Pilcher, and other cars. In this system the oil is forced through the bearings,¹ from which it is drained, filtered, and re-used, with the great advantage that it only circulates whilst the engine runs. Ring lubrication also gives a good approximation to it,² and in many of the best-known cars the crank-shaft

¹ A fundamental condition for efficient lubrication is that the oil must be fed into the bearing at the slack side.

² The bearings are made in such a way that a collar or ring on the shaft, just fitting it and revolving with it, dips into the oil in the well, there being a break in the bearing at its center to allow of this. Of course, with this arrangement the oil is being constantly lifted from the well by the ring as it revolves, flowing down from its highest position into the bearing, and back into the well again.

bearings are fitted with these useful devices, each bearing having a lubricating well, which is from time to time supplied with oil from the oil sights on the dashboard, or from an oil reservoir by a hand-pump, as in the Decauville car.

The important crank-pin bearings are generally lubricated by partly filling the crank-chamber with a cylinder¹ oil to such a height as to allow the ends of the connecting rods to dip a little into it, and in so doing lubricate the crank-pins each time they come into their lowest position; this causes a deal of splashing, which is invariably utilized to lubricate the cylinder by wetting the bottom of the piston² and the wall of the lower part of the cylinder. After a time this oil becomes vitiated and requires changing,³ and it is as well to do this about every 50 or 60 to 100 miles, according to the size of the engine, the smaller ones requiring most frequent attention. The lubrication of most of the other important bearings is pretty generally performed by a sight-

¹The practice of supplying oil to the crank-chamber in doses, and trusting to its being splashed over the gudgeon-pin and cylinder wall, is the one generally adopted, and although rather haphazard, it seems to work well, but as the oil has to lubricate the cylinder, it must be of good quality, suitable for cylinder use. Sometimes an additional drip lubricator feeds oil to the cylinder wall near the lowest position of the piston, but unless this is forced by some means, a thin oil has to be used, and then, for obvious reasons, it is of doubtful utility.

²A grooved ring is sometimes fitted into the bottom of the cylinder, so that the oil may accumulate in the groove, and the ring end of the bottom of the piston dip into it, smearing the cylinder wall with oil from it each up-stroke.

³This is done by unscrewing a plug at the bottom of the crank-chamber and allowing the oil to escape, the fresh oil being poured into the chamber (till it is about a third full) through a similar hole in its upper part. It is necessary to occasionally wash out the chamber with paraffin to keep it clean; and to prevent an excess of oil accumulating in the chamber, an overflow pipe is sometimes fitted, as, should the chamber become too full, too much oil is apt to find its way into the cylinder and lodge between the points of the sparking plug, impairing ignition.

feed lubricator, which should be regulated not so much for a large supply, but for a certain and continuous flow. In some of these lubricators all the tubes are governed by one tap, which is the only one that requires opening and shutting, the others having been once adjusted for the feed required in each case. Needless to say, the efficiency of this system largely depends upon the tubes being kept clean and free from obstructions. In many cars lubrication is effected by an automatic positive feed arrangement, the oil distribution commencing automatically when the engine is started, and ceasing when stopped, no turning on or off being required. An interesting example of this type is fitted to the Lanchester cars, where the bottom of the oil-tank is made to fit a spindle running longitudinally through it, so that the upper part of the spindle is in communication with the bulk of the oil, whilst the lower half is opposed to a series of outlets which communicate with the various parts to be lubricated. The spindle, which is rotated by a worm-gear from the half-speed shaft, has a series of pockets or depressions cut in it—one opposite each outlet—so that in rotating these pockets first fill with oil from the tank, and afterwards discharge their contents into the various passages for distribution.

In some systems of lubrication provision is made to prevent the flow of oil being affected by cold weather. Thus in the fine Crossley car, the oil is forced from the main tank by exhaust pressure¹ to water-heated *sights* on the front of the dashboard, the oil being thus kept warm, and its flow constant at all temperatures of the atmosphere.

Change-speed gears generally run in thick oil,² the

¹ In the James and Browne lubricator, oil is supplied from the tank through sight-feed glasses, by pressure derived from an induced vacuum on the crank-chamber.

² Grease is sometimes used for this purpose, but if this be too viscous to flow, the wheels cut for themselves races in the body of the stuff in which they revolve, more or less

gear-case being occasionally partly filled with it, after drawing off the old and dirty oil. The more out of sight a bearing may be, or the smaller the amount of motion in it, the more likely it is to be neglected, as, even if it works dry, the feeble squeaking noise it makes is often unheard. This particularly applies to parts which are ordinarily lubricated with the common oil-can, such as the regulating mechanism, the valve-rod thrust bearing, lever hinges and the steering gear, which require regular attention. Even the leaves of the springs require occasional greasing,¹ or they will grind on one another and become noisy. On many cars Stauffer grease-boxes are fitted to some of the minor parts; these require screwing up about an eighth of a turn for every 60 to 100 miles run. The advantage of this arrangement is, that should a bearing run hot, the grease melts and flows over the journal.² Beginners usually err on the side of using far too much oil,³ but this is a fault on the right side, and with any given car only experience with close observation will teach its driver how to judiciously use an expensive material, and keep his mount in the pink of running condition. After a time, the temptation with some to take liberties with the car is great, and they may even run it a whole day without attending to its lubrication, but such a liberty as this cannot be taken every day without at least serious depreciation occurring.

70. Lubricating Oils for the cylinders must be of a from contact with the lubricant. The same thing occurs with oils that solidify at temperatures that can hardly be considered low. In the best practice, the bearings in the gear-case are independently lubricated, as the oil in the case becomes charged with metal dust and small chips from the wheels.

¹This is done by jacking up the frame till the leaves of the spring can be separated a little by a screwdriver, when grease is introduced with a knife.

²The part of the shaft or spindle which runs in the bearing.

³About one gallon per thousand miles appears to be a fair allowance for a good-sized car.

kind specially suitable for use at high temperatures, therefore we are precluded from using vegetable and animal oils for this purpose, as they partially decompose at high temperatures, liberating fatty acids, and forming pitch. But mineral oils stand heat much better, and are, therefore, exclusively used for cylinders, and also, as a matter of fact, for most engine lubricating purposes.

High-class cylinder oils are very expensive; their manufacture is in the hands of a very few, and the poor motorist, who must have the best if he is to be economical, must patiently wait for some relief till the Macalpine process is commercially worked on a fairly large scale.

Needless to say, the many secondary bearings about a car can be efficiently lubricated by a high-class heavy machinery oil, but it is best to follow the advice of the maker in these matters. The preparation and use of *grease* has been referred to in the article on Chains, and need not be further touched on. Other matters relating to lubrication have also been explained in various connections, and are therefore not mentioned in this article, which could be profitably much extended if the exigencies of space would permit.

71. Fuel Efficiency of the Car.—We have seen in Article 23 that all the energy of the fuel we can expect to get in the form of work at the crank-shaft is 15 per cent., but there are further serious losses, due to friction, before power is available at the driving wheels. Thus we must expect a loss of about 15 per cent. from crank-shaft to propeller-shaft through the friction in the gear-box, and a further loss of, say, 20 per cent. from propeller to cross-shaft after the bevel wheels have worn a bit, and a still further loss of 15 per cent. from the cross-shaft to the road wheels through the more or less dirty chains; this of course means that the total efficiency may be $\frac{85 \times 80 \times 85 \times 15}{100 \times 100 \times 100 \times 100} = 0.867$, or 8.67 per cent., or only a little more than one-twelfth of the

potential energy of the fuel is available as useful work at the tires of the driving wheels.

72. On Selecting a Car.—The great motor car exhibitions never fail to attract numbers of intending purchasers. Not a few of these having formed ideas as to what they want, they have decided upon the sum of money they will lay out, the form and general arrangement of the tonneau, and perhaps even its color, the number of cylinders and approximate power of the engine have been settled, whilst the kind of transmission, the ignition, lubricating and cooling systems, and the many other important features their ideal car is to have, have been thought out; but, after a painstaking tour of the stands, the potential motorist will find the nearest approach to his requirements is a compromise, as, indeed, every car is; but there is generally on any well-known car some particular feature that is more perfect in its way than that on others in the market, and this is often why a certain car is selected in preference to others. Of course, if this feature is a really important one, one that represents higher efficiency, increased simplicity or greater durability, then the selection may be a very judicious one, but if, on the other hand, it is merely the form, or even the color and finish of the body, as perhaps it more often is than some purchasers would willingly admit, the least said about the matter the better. Not so very long ago it was far from an easy matter to select a satisfactory American made car, but fortunately that is not the case now, as cars more perfect in design, materials, workmanship, construction, finish, and durability are not to be found anywhere in Europe than those which are turned out by our most famous makers. And this can be safely said whilst bearing in mind and duly appreciating the splendid vehicles that have been and are being constructed abroad, more particularly those which owe their development to French, English, and German genius.

73. Car Driving.—The principal makers of cars and motor cycles supply their customers with printed par-

ticulars of all the important details of their vehicles, and, in addition, very concise driving directions; they also, as a rule, willingly allow purchasers to spend a few days in their works to enable them to become acquainted with the internal economy of the mounts they purchase. This is a privilege that everyone should avail himself of, even if he employs a professional driver, as it is only by getting a good grasp of how everything is arranged in a car, and of how the principal adjustments and connections are made, in fact, by learning the functions of every detail of the mechanism of his car, that he will in time become independent of a driver's company or assistance, when such is not desired, and be able to detect any attempt to impose where repairs are concerned. A purchaser should always arrange with the maker for a few lessons in driving, and for one or two long runs; he will then be taught the use of the various handles, levers, fittings, and accessories used by the driver in running the car, and will be shown how the speed of the engine can be varied by advancing and retarding the spark, also by varying and throttling the mixture, and by a combination of these. The ignition system will be explained, and he will be shown how the accumulators are tested and the current switched on and off. The lubricating system will be carefully traced out, and he will learn what to do, so that in starting the car everything that requires it will be properly lubricated, whilst the use of the clutch and accelerator will be made clear, and the action of the cooling system gone into. After the owner has been through all this, he will be taken out for a trial spin on some quiet road, or perhaps in one of the parks early some morning, and he will be able to get a little actual driving practice, at first with the car running on its lowest speed: he will then soon find that there is much to learn before he can with any confidence steer the vehicle, manipulate the clutch, and apply the brake to stop the car with the skill required to avoid sudden strains and shocks. After he has shown some

proficiency in these matters, he will be taught how to change the gear from a low one to a higher, and from a high one to a lower, without injuring the teeth of the wheels; he will be warned against trying to reverse the car by changing the gear before it has been brought to a standstill. But all this time he may have been merely doing the fancy work (which can be mastered in a very short time), his instructor controlling the running of the engine by advancing or retarding the spark and regulating the throttle, operations that he will, after the first two or three lessons, soon begin to perform with a fair amount of readiness. Only experience of this kind will enable him to master the art of driving in such a way that he almost instinctively knows what to do the instant any adjustment is required. It is hardly necessary to remark that the qualities necessary to make a good driver are not possessed by everyone, but it is simply astonishing to find that so many possess an instinctive aptitude for motoring. They are soon able, without any previous mechanical training, to skillfully manipulate their car, and intelligently diagnose the cause of stoppage, and if they have nerve and presence of mind, they are equipped by nature to enjoy to the full a delightful pastime, for there is a peculiar and indescribable pleasure in feeling that you have at your command an obedient agent that will instantly respond to your slightest command, and, should your car be a fairly powerful one, carry you up the steepest hill with a rush that must be experienced to be appreciated; indeed, the only rational excuse for using a powerful car is to be able to negotiate hills at the legal limit speed, and to rapidly accelerate speed after slowing down or stopping; but this very power is one that is too often abused by unskillful owners and inconsiderate and careless drivers, particularly in the abnormal use of the main brakes, which are worked by the side hand lever, which is really an emergency brake, one that should only be used when it is necessary to pull the car up very short to avoid an accident, and it can never

be effectively used without the tires in particular suffering. A skillful and careful driver always assumes, on approaching a cross-road, that something is about to move out of it that might come in his way, or in nearing a bend or turn in the road that there is a flock of sheep approaching, or something of the kind blocking the way; he then slows down enough to enable him to pull up the car in time, by instantly but gradually applying the foot-brake. It will be seen that all this really represents organized common sense; it means that a reliable good car can be driven for years with little depreciation, and the annual expenditure of a comparatively small amount on repairs and up-keep, if it is carefully and cleanly kept in running condition, all bolts and nuts liable to work loose being examined, and screwed up when necessary after each trip, due attention being paid to lubrication, and the car itself driven with a sympathetic consideration for its powers of endurance. On the other hand, it means that if the car is roughly used, the teeth of the gear wheels may be stripped, many parts severely strained, and the driving tires practically destroyed in a very few minutes.

It should not be overlooked that in locomotive practice a man has to spend years in qualifying to take charge of an engine, and even then he is not competent to execute repairs, nor is required to do so; and in almost every case, unless a motor-car driver be a trained mechanical engineer, or at least has had some good workshop experience, it is false economy to allow him to even take up brasses and do such jobs; as to perform them satisfactorily no small amount of skill is required. It would not be going too far to say that the least important part of the training of a driver is that which enables him to take charge of the wheel and skillfully steer a car through crowded traffic. The really proficient man is able to detect the slightest thing abnormal about the running of a car, and locate its cause before anything serious occurs. And if his training has been of the right kind, and he takes a pride in his work, he

will keep his car so that everything about it is in the pink of condition, and screwed up to concert pitch when required for use.

74. How to Start a Car.—As some reader may become possessed of a second-hand¹ car, and therefore will not be in so fortunate a position, so far as tuition is concerned, as the owner of a new car, it will be as well to very briefly explain what is usually done in starting the engine and car. But as much information bearing on driving has been given in the articles on Ignition, Cooling, Gear-changing, Carburation, and Carburettors, etc., the references to these matters will be very brief. The first thing that may be done, is to see that the tanks are filled with enough gasoline and water for the purposed run, and then make sure that all the working parts are thoroughly lubricated, and that the sight-feed lubricators are adjusted. Next turn on the gasoline to supply the carburettor, and flood the latter by moving the float-needle up and down two or three times, fully opening the mixture throttle, push *on* the electric switch, and retard the ignition to prevent back-firing; then place the change-speed lever in the neutral position, and smartly turn the starting handle till the explosions drive the engine, being careful always to exert the effort in pulling the handle upwards, and refrain from pushing it downwards, as, should back-firing accidentally occur whilst it is being pushed down,

¹No one who is not an experienced mechanical engineer should be tempted to buy a second-hand car without the advice of an expert, as the art of the horse dealer in doctoring a horse is not to be compared with that which is sometimes practiced in preparing old-fashioned, or even obsolete, cars for sale. In many cases, too, modern cars that have been very badly treated, and whose mechanisms are practically worn out, are made to look like new ones, to say nothing of the freaks which are faked. On the other hand, excellent cars can be picked up sometimes at less than half their original cost, as some owners are never long satisfied with their vehicles, and must have a new one at least once a year.

it would be violently and suddenly forced upwards, with almost certain injury to the arm. The clutch-pedal may now be depressed, and the gear-lever pulled over till the gear for the first speed¹ is in mesh, and the latch of the lever slips into its notch in the quadrant, when the clutch may be gently let in to allow the car to gradually accelerate its speed. (Refer to Article 61.)

CONCLUDING REMARKS

75. In looking over the contents of this little work, the author is forcibly reminded that many matters which could not fail to interest the motor novice have been omitted owing to the want of space. This being so, brief reference to some of the more important omissions may be made in this concluding article.

One of the qualities of a car which does not generally receive the attention it deserves is ACCESSIBILITY; it is true that much has been done to improve cars in this direction during the past year or two, but, although it is quite the exception to find engines whose valves are not readily accessible, the same thing can scarcely be said for clutches, which should always be arranged so that an adjustment is easily made; and many other parts, such as gear-cases, differentials, etc., should be get-at-able in the sense that they can be taken out for repairs without dismantling half the car; and, more particularly, in every case those parts which periodically require adjusting, or occasional attention on the road, should be as accessible as possible. In some cars the driving and controlling fittings are not placed so that they can be worked with ease by drivers whose arms and legs are of average length; this is particularly the case with push pedals, which might with advantage be

¹Needless to say, the novice should wait till he is proficient in driving on the lowest speed before he attempts to run his car on a higher one.

made adjustable, as (spinal columns being fairly constant in length) the difference between a tall person and a short one is mainly one of legs. RELIABILITY is a quality the importance of which cannot be overrated, and the various reliability trials here and abroad, arranged so that absolutely every replenishment, adjustment, and cleansing of the cars was done on the road, under official observation in the running time, have enabled the judges to draw up reports that have greatly assisted designers and makers, and have led to a high standard of reliability being reached. And the same remarks equally apply to the highly successful light car trials recently made.

The question of dust-raising by motor cars has been studied and the results of the experiments now being made are sure to be of great interest to motorists. It has been noticed, in a general way, that cars which have a clean underbody without any projections, the lowest parts at the back being higher than those at the front, the bottom forming a taper clearance, raised the least amount of dust at a given speed. It has also been noticed that the amount of dust raised increases with the size of the tires, other things being the same, and that exhausts impinging on the ground increase the evil; but, fortunately, these are matters that we shall know more about soon, and, if some simple means of mitigating what is fast becoming a grave nuisance, both to motorists and other users of our roads, can be devised, it will be hailed as a great boon. Of course, whatever can be done in this direction will only partly solve the problem, the real solution of which is the making of waterproof roads. But if such roads were once made and used only by automobiles, there would be comparatively little depreciation; as it is, on ordinary roads, the tires lick up and disperse the road detritus (rubbish of attrition), and in so doing accelerate the disintegration of the surface; but, of course, the injury done in this way is slight compared with the hammering effect of horses' feet on the metaling, which sooner

or later destroys the surface, whatever it may be made of. It is not easy to foresee how this road problem is to be ultimately solved, but if motorists continue to increase in number at the present rate, they will ere long be strong enough to influence for the common good those bodies who are responsible for the up-keep of our roads.

STEAM CARS have been greatly improved during the past two or three years, and when their principal points are compared with those of gasoline cars, it is not easy to understand why the former should be so much neglected by the motorist.¹ It is true they did not at one time compare very favorably with the gasoline car; boiler² troubles were frequently heard of, particularly in cases where boilers which required skillful handling were in the hands of careless and inexperienced drivers. Then, again, fuel-consumption was usually excessive, to say nothing about the difficulty of getting a supply of suitable water two or three times on a long run. But all that is a matter of the past, and the modern steam car of the best make can be driven a distance of over a hundred miles without a stop for water or fuel, and with no more attention than is required by the most perfect gasoline car, whilst by using the throttle the range of engine power is so great that no change-speed gear is required, and the condensation of steam is so complete that the exhaust is rarely seen. In addition to these good features, the steamer is a splendid hill climber, and its smooth vibrationless running on a decent road is what many acclaim to be the poetry of motion. Indeed, if, in selecting a car, absence of vibration, for some reason or another, is considered the most important factor, then it would be a safe plan to paraphrase the famous whist injunction—"When in doubt, select a steamer," and a selection could safely be made from

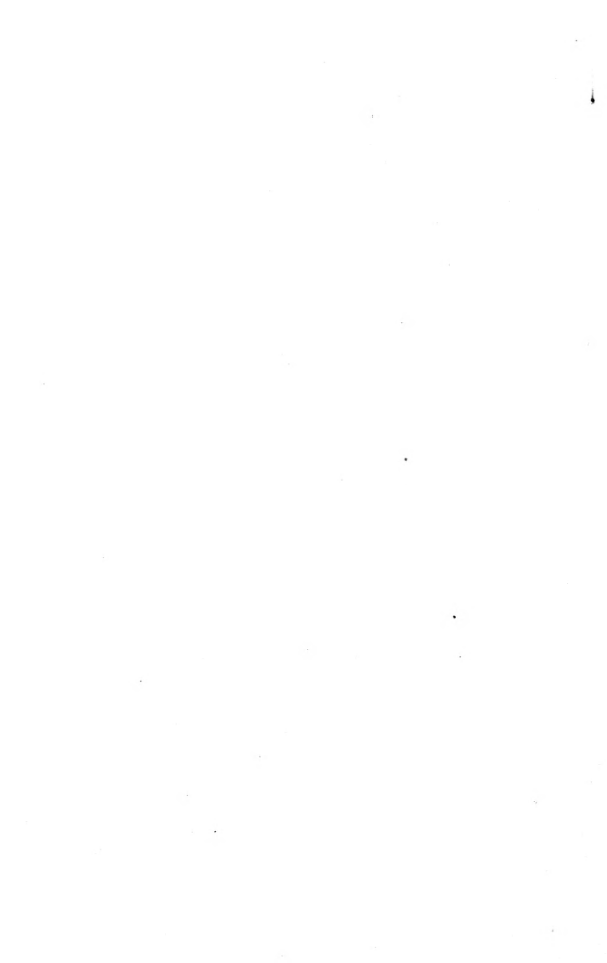
¹ Refer to Article 2, where it will be seen that the variety of steam cars is small compared with gasoline ones.

² Makers prefer to call these *steam generators*, or, briefly, *generators*.

the foreign Miesse, or Serpollet,¹ or the American White, to mention only three of the best known. Doubtless, ere long, more attention will be paid to the relative merits of the two systems, but, for the nonce, everyone knows that, rightly or wrongly, the gasolene car is an easy first favorite, and the fundamental fact that it is more economical to burn the fuel in the cylinder of the engine than in a boiler will always be in its favor, notwithstanding its drawbacks and the possibilities of trouble in connection with carburettors and ignition systems.

Should the day-dreams of some of our advanced thinkers ever eventuate in the creation of a gasolene turbine of great range of power and moderate weight, it is safe to say that a new era in automobilism would rapidly dawn. But even taking things as they are, it is possible for any man who can afford to keep a dog-cart, to run a light car and bring a new joy into his life, with little or no additional expense, if he is mechanically inclined, and is not afraid of attending to the car himself.

¹ Mons. Serpollet has perhaps done more than any man living to develop the possibilities of the steam car. Indeed, it can be safely said that what he does not know about flash boilers it is not worth knowing.



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